Publication No. 85-e26

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M E M O R A N D U M
February 27, 1985

To: Jim Krull

From: Dale Norton D.N. and Art Johnson, aj Water Quality Investigations Section

Subject: Completion Report on WQIS Project 1 for the Commencement Bay Near-shore/Tideflats Remedial Investigation: Assessment of Log Sort Yards as Metals Sources to Commencement Bay Waterways, November 1983 - June 1984

ABSTRACT

Metals concentrations were measured in runoff from twelve log sort yards on the Tacoma tideflats and in the adjacent surface waters and sediments of Blair and Hylebos Waterways. High concentrations of arsenic, zinc, copper, and lead were present in runoff from ten yards. Surface runoff from four sort yards was monitored during five storm events. These data, sort yard acreages, annual rainfall, and less frequent sampling of the remaining yards were used in concert with runoff calculations to estimate metals loadings from all yards. The combined annual metals loads (pounds/year) to Commencement Bay waterways from all twelve yards were estimated to be: arsenic, 2500; zinc, 1100; copper, 510; lead, 310; nickel, 66; antimony, 50; and cadmium, 2.0. Because it appears surface runoff accounts for only about 40 percent of the rainfall in these sort yards, there is a strong probability that contaminated groundwater may be a substantial additional source of metals flux to the waterways.

Peak concentrations of arsenic, zinc, and copper in surface water and sediments in Blair and Hylebos Waterways were recorded in the vicinity of the log sort yards. EPA acute criteria for the protection of saltwater aquatic life were exceeded for zinc and copper in Blair and Hylebos surface waters adjacent to discharges from Murry Pacific yards #1 and #2 as well as the Wasser/Winters yard.

The use of ASARCO slag for ballast at the log sort yards is, in all probability, the major source of elevated metals concentrations seen in log sort yard run-off, nearshore surface waters, and sediments.

Memo to Jim Krull
Completion Report on WQIS Project 1 for the Commencement Bay Nearshore/Tideflats Remedial Investigation: Assessment of Log Sort Yards as Metals Sources to Commencement Bay Waterways, November 1983 - June 1984

INTRODUCTION

The Water Quality Investigations Section (WQIS) had responsibility for five projects† in the Commencement Bay Nearshore/Tideflats Remedial Investigation. The objective of Project No. 1 was to evaluate runoff from log sort yards located on the Tacoma tideflats as a source of metals to Commencement Bay waterways.

In November 1980, the Environmental Protection Agency released a report showing high concentrations of arsenic and zinc were present in a sample of surface runoff collected on September 24, 1980, from Murry Pacific Corporation's log sort yard #2 on Blair Waterway (EPA, 1980a, sample no. 38318). In an effort to verify this finding, inspectors from the WDOE Southwest Regional Office (SWRO) collected additional runoff samples from this yard as well as several other yards on the Tacoma tideflats. These samples also contained high concentrations of arsenic and zinc as well as copper, lead, nickel, and antimony. The source of these metals was suspected to be ASARCO slag which was used by a number of yards as ballast to stabilize the yard surface (see Figure A in appendix). SWRO inspectors theorized the slag was being pulverized by heavy equipment and subsequently mobilized by a combination of acid rain, storm runoff, and woodwaste extracts (Pierce and Anderson, 1982).

As a result of these initial investigations, a meeting was held on March 17, 1981, with the sort yard operators, in which a verbal agreement was reached to stop using slag until more definitive information could be obtained concerning metals in sort yard runoff. Prior to this meeting, nine of the twelve log sort yards operating on the tideflats were known to have used ASARCO slag for ballast. Only one yard is known to have returned to using slag since the March 1981 agreement.

†WQIS projects:

- No. 1 - Assessment of Log Sort Yards as Metals Sources to Commencement Bay Waterways
- No. 2 - Metals in Hylebos Creek Drainage
- No. 3 - Point Source Monitoring
- No. 4 - Source Evaluation for Metals in Sitcum Waterway Sediments
- No. 5.1 - Priority Pollutants - City Waterway Storm Drains
- No. 5.2 - Metals in City Waterway Sediments
- No. 5.3 - Petroleum Compounds in D Street Groundwater and Adjacent City Waterway Sediment

SITE DESCRIPTION

The locations of the twelve sort yards on the Tacoma tideflats are shown in Figure 1. Table 1 gives additional information on status, size, and amount of slag applied. For most yards there are no data on slag usage.

Table 1. Tacoma tideflats log sort yards.

Sort Yard	Status†	Acres	Receiving Water	Slag Usage* Date	Slag Usage* Tons
Cascade Timber Yard #1	Inactive	6.6	Hylebos Waterway	--	--
" " " #2	Active	13.5	Hylebos Waterway	--	--
" " " #3	"	20.4	Sitcum Waterway	--	--
Dunlap Towing	Inactive	16.6	Hylebos Waterway	12/79-05/80	1,103
Louisiana Pacific	Active	18.3	" "	--	--
McFarland Cascade	"	14.1	Puyallup River	--	--
Murry Pacific Yard #1	"	18.0	Hylebos Waterway	1975-80	29,225
" " " #2	"	50.8	Blair Waterway	1975-80	68,071
Portac	"	28.2	Wapato Cr/Blair WW	1983	12,122[a]
St. Regis Sort Yard	"	56.4	St. Paul Waterway	--	--
Wasser/Winters	"	11.7	Hylebos Waterway	--	--
Weyerhaeuser	"	23.3	Hylebos Waterway	Paved	

† = As of June 29, 1984.
* = Source: WDOE SWRO files.
-- = No data
a = Personal communication from Gene Balch, Portac.

Eight of these yards--Cascade Timber yards #1, #2, and #3, Dunlap Towing, Murry Pacific yards #1 and #2, Wasser/Winters, and Weyerhaeuser--are primarily involved with the handling and storage of logs. St. Regis, Portac, and Louisiana Pacific are combination sort yard and sawmill operations. McFarland Cascade is a pole-treating facility. The Weyerhaeuser yard is unique among Tacoma sort yards in being completely paved. The sawmill portions of the combination facilities are also paved, but were not part of this investigation.

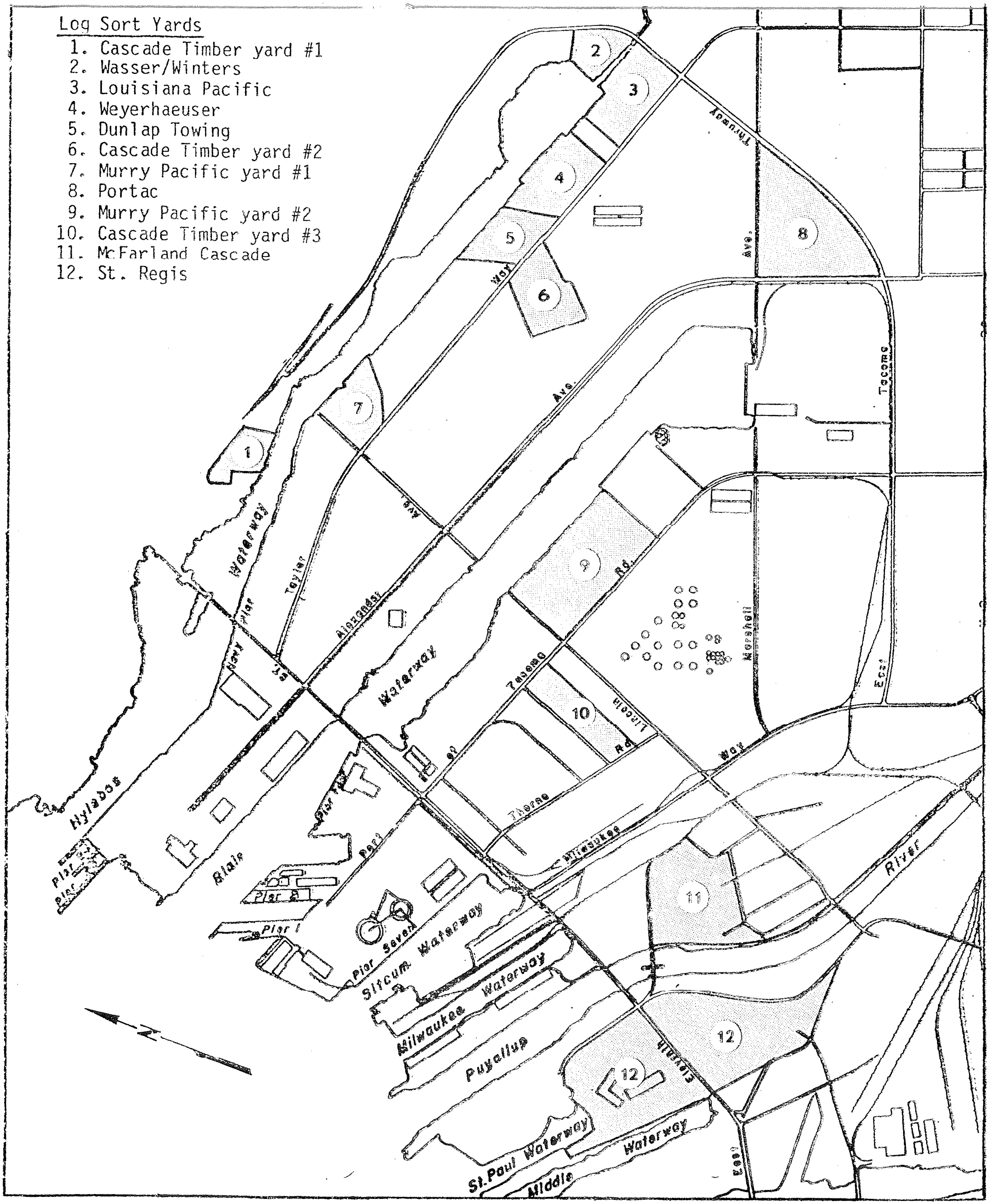

Figure 1. Locations of log sort yards on Tacoma tideflats, 1983-1984.

METHODS

Survey Design

To characterize metal concentrations and drainage patterns, a reconnaissance survey was made at each of the twelve sort yards on November 4, 1983. Based on results from analysis of the runoff samples collected, four yards--Murry Pacific yards #1 and #2, Portac, and Wasser/Winters--were chosen for routine monitoring during the 1983-1984 wet-weather season. These yards were selected for monitoring because (1) all had made extensive use of slag, (2) their runoff had high metals concentrations (Appendix I), and (3) all possessed definable drainages (i.e., all or most surface runoff channeled into ditches or pipes prior to discharge).

The locations of all discharges sampled during this survey are shown in Figures 2a - 2e. A listing of station numbers entered in the Commencement Bay data base that correspond to the WDOE station numbers in Figures 2a - 2e are in Appendix II. The number of discharges sampled from each of the four monitoring yards were as follows: Murry Pacific yard #2 - 11; Portac - 3; Wasser/Winters - 6; and Murry Pacific yard #1 - 3.

The routine monitoring surveys were conducted on December 12, 1983, and March 12, April 10, and May 3, 1984. Each survey took about four hours. Grab samples for total and dissolved metals (arsenic, zinc, copper, lead, nickel, antimony, and cadmium), pH, specific conductivity, total suspended solids, and total non-volatile suspended solids determinations were collected at all yard discharges. Instantaneous flows were measured at all drains.

The amount of rainfall preceding and during each sample collection is shown in Table 2.

Table 2. Daily rainfall* preceding WDOE log sort yards sample collections between November 1983 and June 1984. (Collection date underlined.)

Date	Rainfall (inches)	Date	Rainfall (inches)
10/30/83	0.33	04/05/84	0.08
10/31/83	0.05	04/06/84	0
11/01/83	0.21	04/07/84	0.70
11/02/83	0.21	04/08/84	0.01
11/03/83	1.61	04/09/84	0.13
11/04/83	0.46	04/10/84	0.32
12/07/83	0.23	04/28/84	0
12/08/83	0.43	04/29/84	0
12/09/83	0.55	04/30/84	0.31
12/10/83	1.00	05/01/84	0.35
12/11/83	0.10	05/02/84	0.61
12/12/83	0.26	05/03/84	0.21
12/24/83	0	06/24/84	0
12/25/83	0.01	06/25/84	0
12/26/83	0.12	06/26/84	0
12/27/83	0.10	06/27/84	0.40
12/28/83	Trace	06/28/84	Trace
12/29/83	0.79	06/29/84	0.68
03/07/84	0		
03/08/84	0		
03/09/84	0		
03/10/84	0.10		
03/11/84	0		
03/12/84	0.60		

*Data provided by Raymond Redding, Tacoma Central Treatment Plant #1.

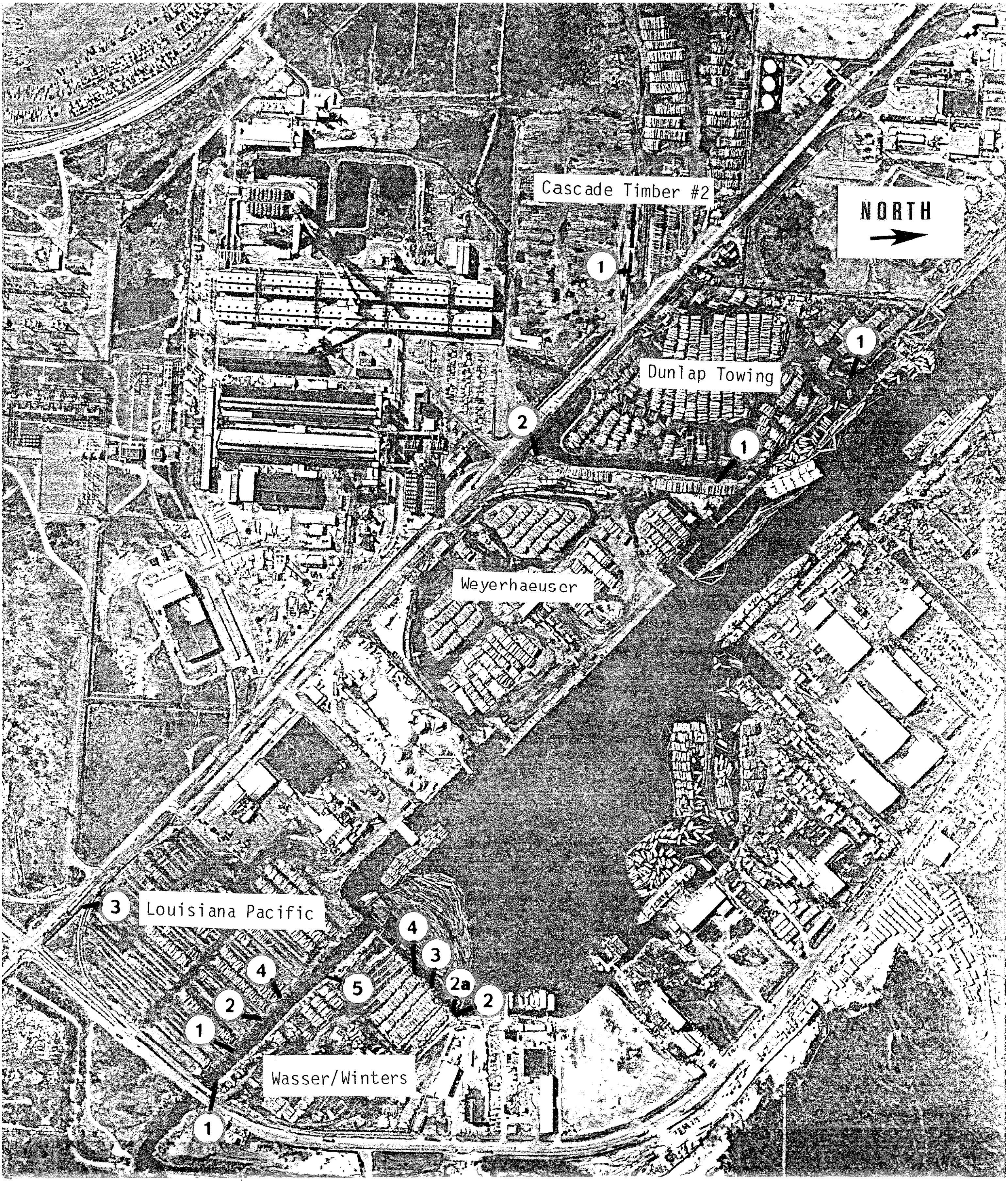

Figure 2a. WDOE station locations for Tacoma tideflats log sort yards, November 4, 1983-June 29, 1984.

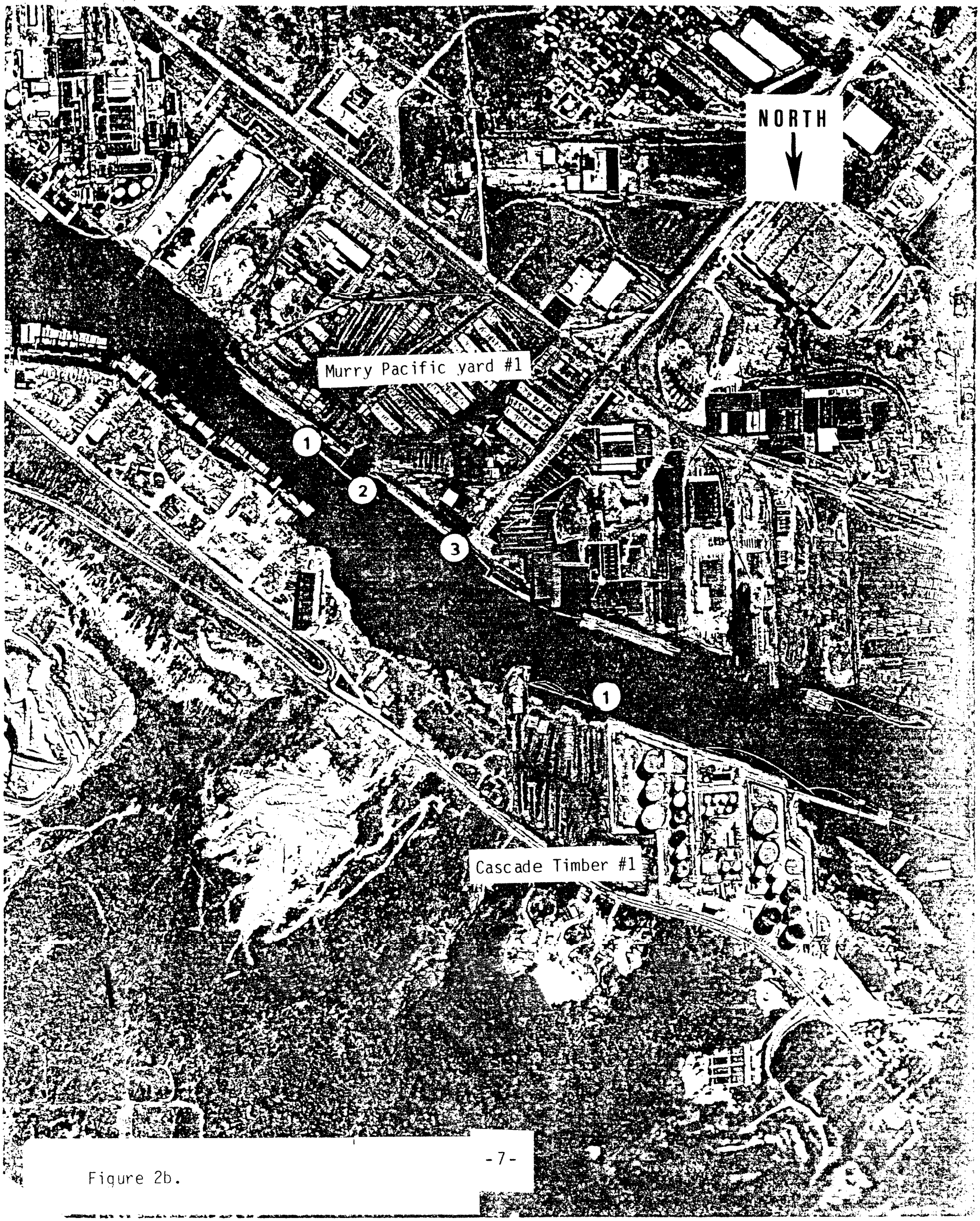

Figure 2b.

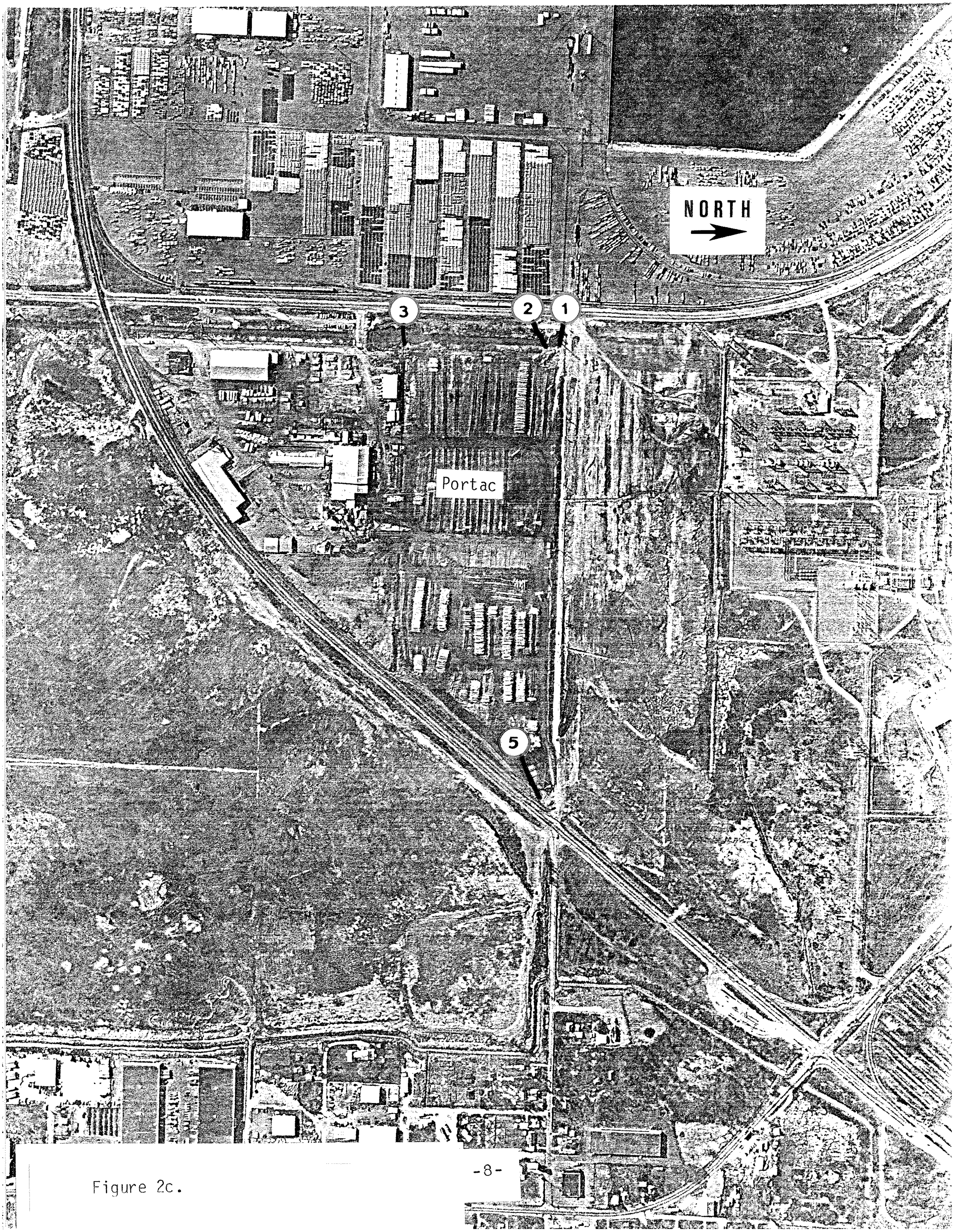

Figure 2c.

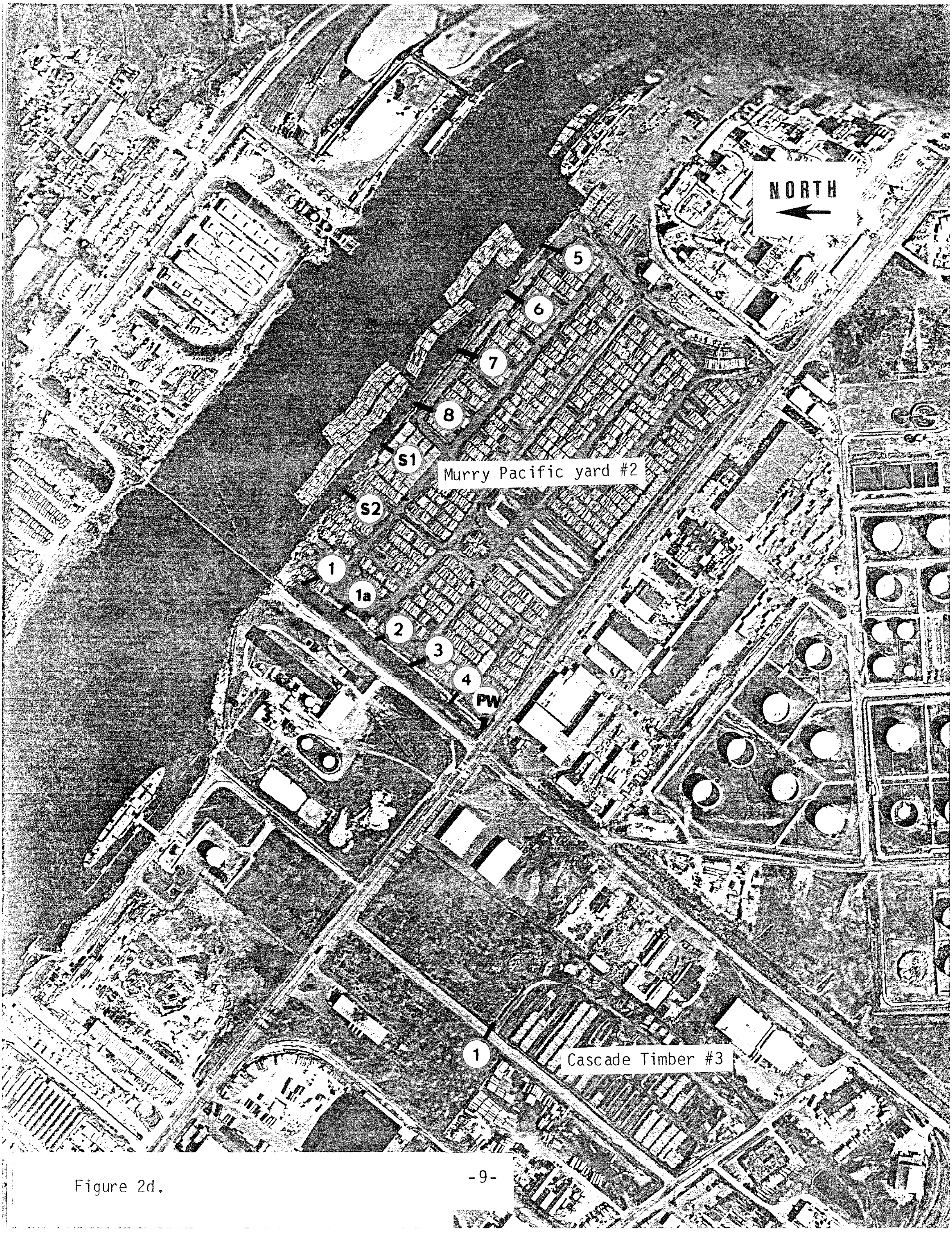
NORTH
5
6
7
8
S1
Murry Pacific yard #2
S2
1
1a
2
3
4
PW
1
Cascade Timber #3

Figure 2d.

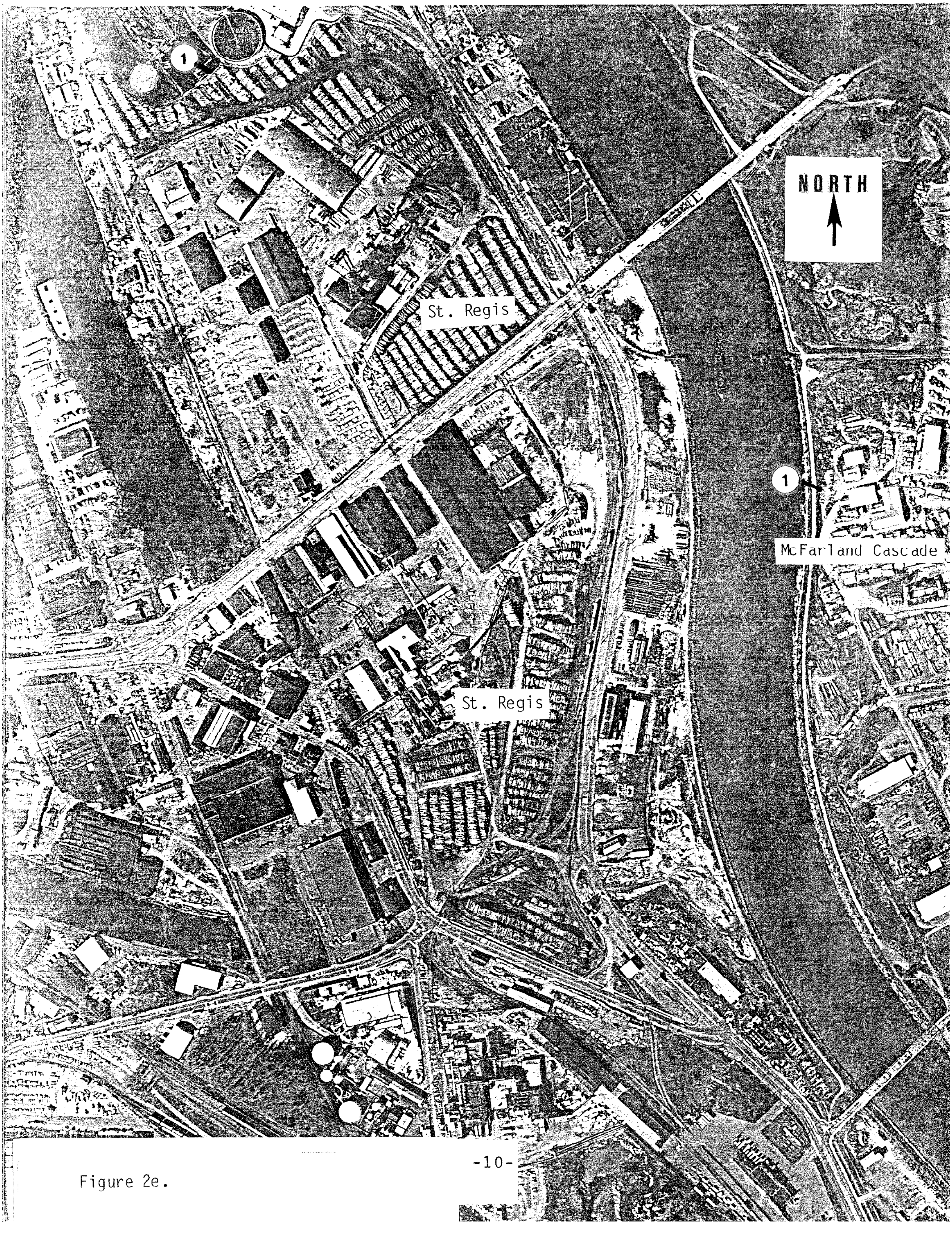

Figure 2e.

Sampling was conducted immediately following sufficient rainfall to produce surface runoff from the sort yards. At least 0.70 inch of rain fell in the 72 hours prior to all sample collections.

To assess the impact of sort yard runoff on the receiving environment, water and sediment samples were collected from Hylebos and Blair Waterways. Water samples were collected during an ebbing tide near each of the four routine monitoring yards and along a mid-channel transect. This receiving environment sampling was done concurrently with the May 3, 1984, routine collection of sort yard runoff. All samples were collected as grabs by submerging the container approximately six inches below the surface. These samples were analyzed for metals, pH, salinity, and total suspended solids. In addition, grab samples were collected above and below Wasser/Winters discharges to Hylebos Creek and Portac discharges to Wapato Creek. Station locations are shown in Figure 3.

Subtidal sediments were collected on June 16, 1984, from eight sites each in Blair and Hylebos Waterways. Both nearshore and offshore samples were collected near each yard, as shown in Figure 4. Sediment samples were analyzed for metals, percent moisture, total organic carbon, nitrogen, and grain size. Coordinates for these stations and other location information are in Table 3.

Sample Collection and Analysis

Water - Metals samples were collected as grabs in new one-quart polyethylene cubitainers previously rinsed with deionized water. Samples were acidified at the WDOE Tumwater, Washington, laboratory to pH ≤ 2 with HNO_3 within twenty-four hours of collection, and transported to the EPA/WDOE Region X laboratory in Manchester, Washington, for analysis. Analysis was by atomic absorption spectrometry using a graphite furnace following EPA (1979) Methods for Chemical Analysis of Water and Wastes. Samples for dissolved metals determinations were filtered in the laboratory through a 0.45 micron Millipore filter prior to being acidified.

Samples for conventional water quality parameters (pH, specific conductivity, salinity, total suspended solids, and total non-volatile suspended solids) were collected in half-liter polyethylene bottles. The WDOE Tumwater laboratory did the conventionals analyses. pH was measured with a Corning "pH/ion meter 135." Specific conductivity was determined on a Beckman "model RC-19 conductivity bridge." Salinity was measured using a Beckman "model RS7-C induction salinometer." Total suspended solids and total non-volatile suspended solids analyses were performed within 14 days of collection following Methods 160.2 and 160.4, respectively, in EPA (1979).

Flows were measured with a Marsh-McBirney magnetic flow meter and top-setting rod or alternately, by the bucket-and-stopwatch method, depending on the physical configuration of the sampling location.

All samples were placed on ice immediately after collection. WDOE chain-of-custody procedures were followed.

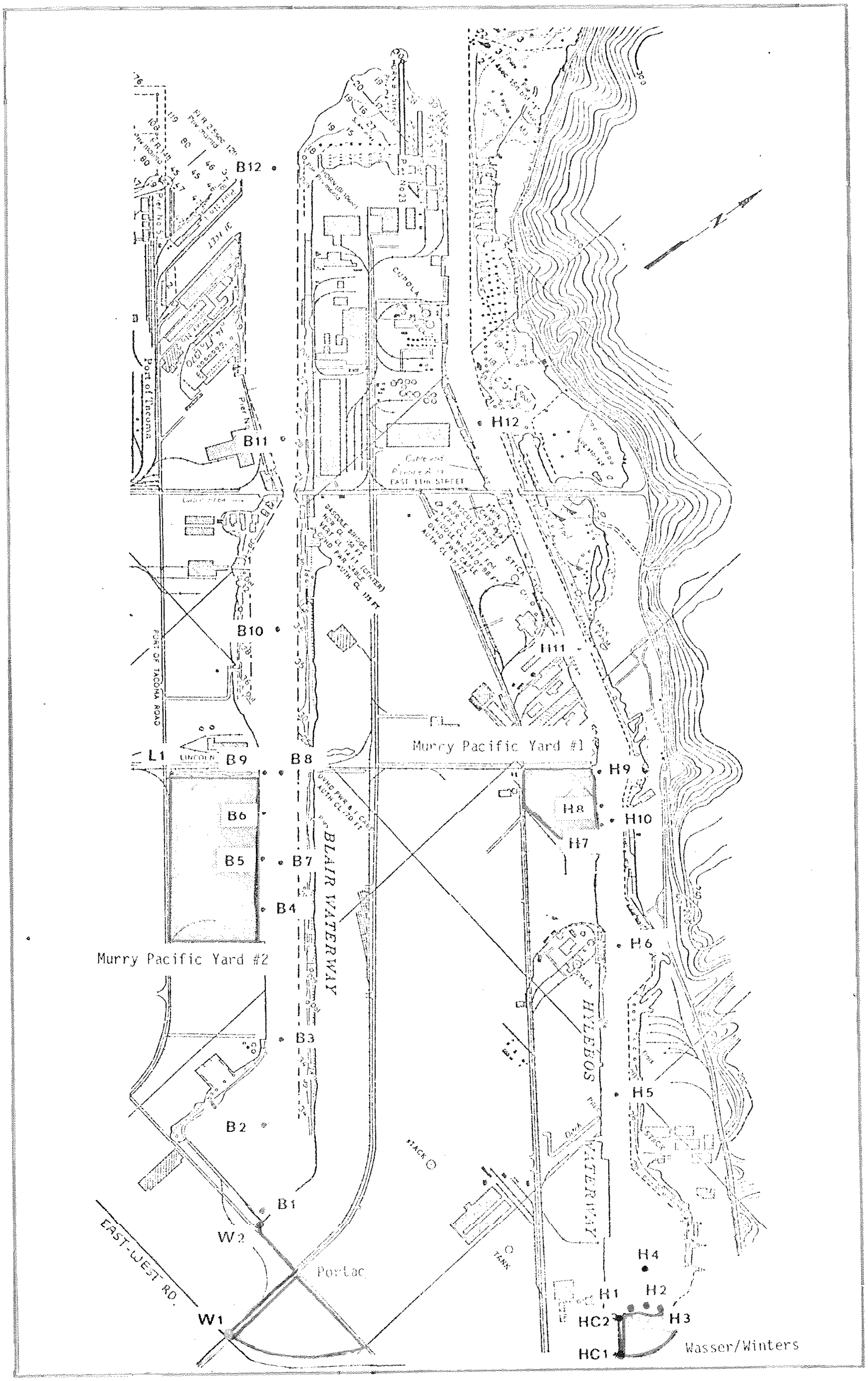

Figure 3. WDOE receiving water station locations in Blair and Hylebos Waterways, May 3, 1984.

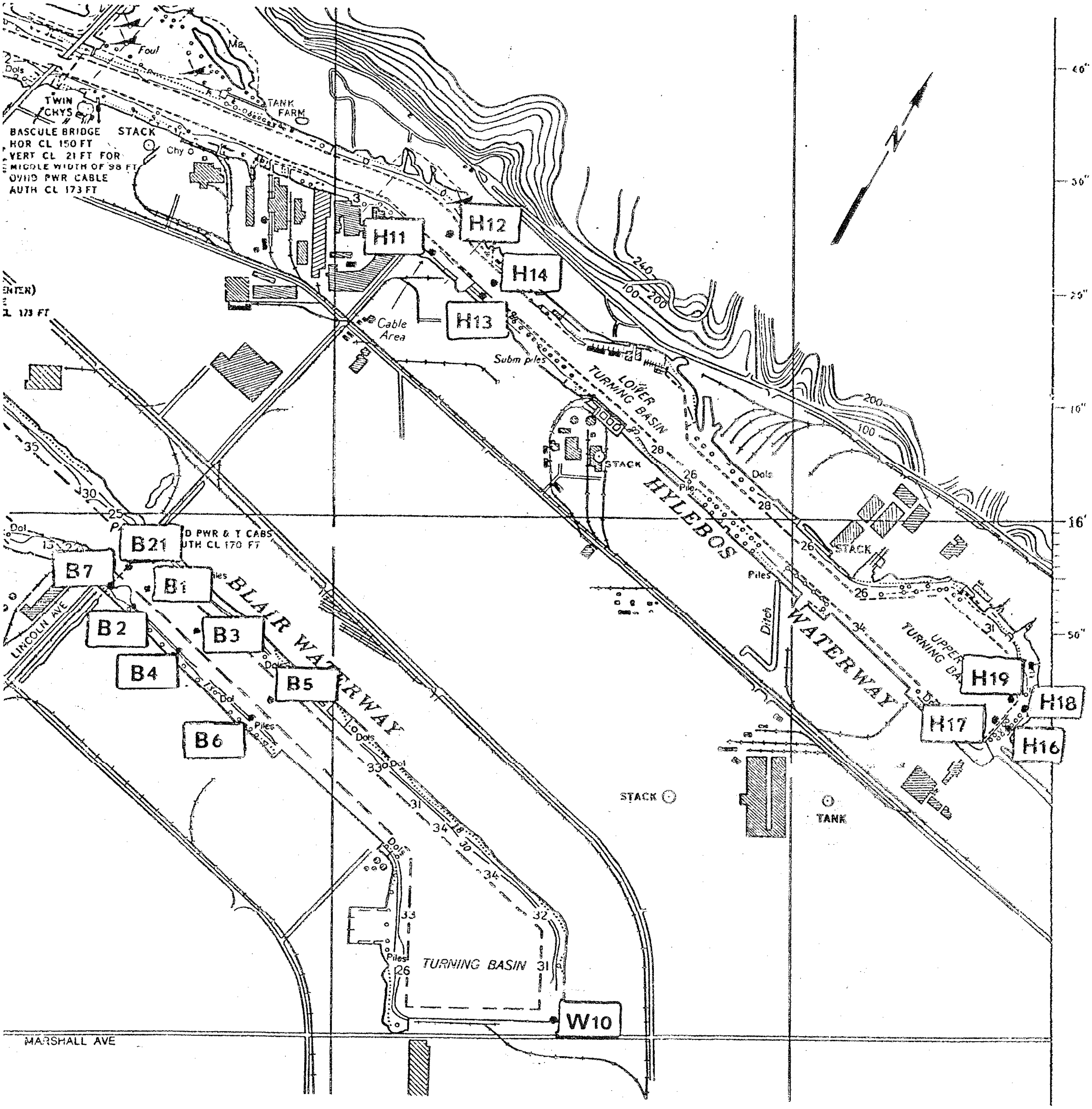

Figure 4. WDOE sediment station locations in Blair and Hylebos Waterways off Tacoma log sort yards, June 14, 1984.

Table 3. Locations of sediment samples collected by WDOE near log sort yards on Blair and Hylebos Waterways and Wapato Creek, June 14, 1984.

Station Number	Station Description	Depth at MLLW (feet)	Latitude 47°	Longitude 122°
BLAIR WATERWAY - MURRY PACIFIC YARD #2				
B-1	200 feet offshore of B-2	40	15'54.5"	23'24"
B-2	50 feet off 1st dolphin from S. Lincoln Ave. ditch	29	15'52"	23'26.5"
B-3	200 feet offshore of B-4	44	15'50"	23'18"
B-4	50 feet offshore of 11th dolphin from S. Lincoln Ave. ditch	29	15'48"	23'20"
B-5	200 feet offshore of B-6	45	15'43.5"	23'8.5"
B-6	50 feet off 4th dolphin from Murry dock	27	15'42"	23'11"
B-7	50 feet off S. Lincoln Ave. ditch	34	15'53"	23'30"
B-21	200 feet offshore of B-7	41	15'56.5"	23'27"
WAPATO CREEK - PORTAC				
W-8	30 feet downstream of East-West road bridge	--	14'56"	22'17"
W-10	intertidal at head of Blair Waterway near mouth of Wapato Cr.	--	15'15"	22'32"
HYLEBOS WATERWAY - MURRY PACIFIC YARD #1				
H-11	50 feet off blue machine shed, south shore	10	16'23.5"	22'47.5"
H-12	160 feet offshore of H-11	27	16'25"	22'45"
H-13	50 feet off main discharge	16	16'19.5"	22'40.5"
H-14	160 feet offshore of H-13	28	16'21"	22'39"
HYLEBOS WATERWAY - WASSER/WINTERS				
H-16	75 feet off south end of yard near log ramp, upper turning basin	28	15'41.5"	21'32"
H-17	120 feet offshore of H-16, upper turning basin	30	15'42.5"	21'33"
H-18	75 feet off north end of yard, upper turning basin	28	15'43.5"	21'30"
H-19	120 feet offshore of H-18, upper turning basin	28	15'44"	21'31"

Sediment - Subtidal sediments were collected using a 0.1 m^2 VanVeen grab. Creekbed sediments were collected by hand with a small polyethylene corer. In both instances, the top 2 cm layer was removed, placed in one-half gallon glass jars, and homogenized by stirring. In the case of creekbed sediments, several cores were composited from each station. The homogenate was split into three subsamples for analysis. Two of the three subsamples were placed into separate 4.5-ounce polyethylene cups for metals and percent moisture analyses, while the third went into a one-pint glass jar to be analyzed for grain size, total organic carbon, and nitrogen. All samples were placed on ice immediately after collection. WDOE chain-of-custody procedures were followed.

Metals analyses on sediment were done at the EPA/WDOE Manchester laboratory. Samples were digested with HNO_3/H_2O_2 following EPA (1982) Test Methods for Evaluation of Solid Waste, then analyzed by atomic absorption spectrometry using a graphite furnace. All metals analyses were according to EPA (1979) Methods for Chemical Analysis of Water and Wastes. Percent moisture was determined at the WDOE Tumwater laboratory using EPA Method 160.3 (EPA, 1979).

Grain size, total organic carbon, and nitrogen analyses were done by an EPA contract laboratory, Rocky Mountain Analytical, in Arvada, Colorado. Samples were shipped via air freight the day of collection, and analyzed following EPA/COE (1981) Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Grain size was determined by the method of seives and pipettes; total organic carbon and nitrogen were determined with a Perkin-Elmer elemental analyzer.

Quality Assurance

These surveys were done in accordance with a quality assurance program (WDOE, 1983) developed following requirements and guidelines set down in the Final QA Program Plan for Commencement Bay Nearshore/Tideflats Remedial Investigation (Tetra Tech, 1983).

The EPA/WDOE Manchester laboratory achieved ±3 percent accuracy on EPA performance evaluation water samples (EMSL, Cincinnati, OH) run as internal laboratory standards; spike recoveries were within the range of 85 to 110 percent (Arp, 1984). Laboratory blanks analyzed separate from field samples as a check against metals contamination from sample containers, HNO_3 preservative, or analytical procedures consistently had metals concentrations at or below limits of detection. Field blanks also were analyzed as part of each water sample collection. These data, in Appendix III, show elevated levels of metals in field blanks for certain surveys. Data were not accepted when field blank concentrations exceeded 20 percent of the sample concentrations. This resulted in seven percent of the data being deleted. All raw data are tabulated in Appendix I.

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Four pairs of duplicate runoff samples were prepared in the laboratory after acidification. The average relative percent difference between duplicates shown below in Table 4 was as follows: arsenic - 3 percent; zinc - 2 percent; copper - 5 percent; lead - 4 percent ; nickel - 30 percent; antimony - 10 percent; and cadmium - 10 percent.

Table 4. Results of metals analysis of duplicate runoff samples (ug/L, total metal).

Date	Arsenic	Zinc	Copper	Lead	Nickel	Antimony	Cadmium
12/29/83	1580	525	254	201	21	--	0.5
	1600	534	267	207	16	--	0.5
Relative percent difference	1	2	5	3	24	--	0
3/12/84	1270	440	--	101	24	75	0.7
	1190	442	--	105	14	66	0.6
Relative percent difference	6	0.005	--	4	42	12	14
4/10/84	8700	3620	2480	383	214	536	3.9
	8500	3410	2530	370	212	459	3.2
Relative percent difference	2	6	2	3	1	14	7
5/3/84	6940	748	444	296	24	137	0.6
	6820	758	405	312	42	132	0.8
Relative percent difference	2	1	9	5	43	4	25
Average relative percent difference	3	2	5	4	30	10	10

-- = no data

A National Bureau of Standards (NBS) standard estuarine sediment sample was nalyzed by the Manchester laboratory to assess the accuracy of sediment metals determinations. As shown in Table 5, the Manchester results coincided with the NBS-determined values for arsenic, copper, and cadmium, but were slightly lower for zinc and lead. Certified values were not available from NBS for antimony.

Table 5. Results of analysis of NBS standard estuarine sediment #1646.

Metal	NBS Certified Value (mg/Kg)	EPA/WDOE Determined Value (mg/Kg)	EPA/WDOE Value as Percent of Stated Value
arsenic	11.6 ± 1.3	11.7	101
zinc	138 ± 6	114	83
copper	18 ± 3	20	110
lead	28.2 ± 1.8	24.1	85
cadmium	0.36 ±0.07	0.38	106

A duplicate sediment sample was also prepared in the field from the grab at station B-7. The duplicate analysis results for metals are shown below in Table 6.

Table 6. Results of metals analysis of duplicate sediment samples from station B-7.

Metal		B-7	B-7 (dup.)	Relative Percent Difference
arsenic	(mg/Kg)	48	50	4
zinc	"	131	140	7
copper	"	106	104	2
lead	"	68	72	6
nickel	"	15	15	0
antimony	"	0.6	0.5	20
cadmium	"	0.5	0.43	10

The conventional sediment data (except percent moisture) were reviewed by Robert Barrick, Tetra Tech, Inc., Bellevue, QA officer for the Commencement Bay project. These data were generally within acceptable QA limits; however, the precision estimate for duplicate measurements stated in the Commencement Bay Quality Assurance Plan (Tetra Tech, 1983) was exceeded for total organic carbon. In addition, nitrogen values below 0.10 percent were treated as estimates (due to laboratory blank contamination). The values shown below in Table 7 were achieved for conventional parameters in the field duplicate.

Table 7. Results of conventionals analysis of duplicate sediment samples from station B-7.

Parameter		B-7	B-7 (dup.)	Relative Percent Difference
Moisture	(%)	46	35	24
Total organic carbon	"	2.4	2.6	8
Nitrogen	"	0.33	0.28	5
Grain Size				
sand > 0.062 mm	"	20.6	21.6	5
silt 0.004 - 0.062	"	61.3	59.7	3
clay < 0.004 mm	"	18.2	18.7	3

Results and Discussion

Runoff

Table 8 summarizes the data collected between November 1983 and May 1984 characterizing runoff from Murry Pacific yards #1 and #2, Portac, and Wasser/Winters. pH and specific conductivity are reported as simple averages; solids and metals are flow-weighted average concentrations[1].

Total instantaneous flows from individual yards ranged from 0.015 MGD to 2.1 MGD. Flow was generally a function of yard size; although in a few cases, changes in rainfall over the course of a survey caused runoff measurements at a small yard to exceed those at a larger yard. Instantaneous flows averaged over the five sampling surveys for each yard were as follows: Murry Pacific yard #2 (50.8 acres) 0.60 MGD; Portac (28.2 acres) 0.48 MGD; Murry Pacific yard #1 (18.0 acres) 0.28 MGD; and Wasser/Winters (11.7 acres) 0.13 MGD.

pH ranged from 5.2 to 6.8 and appeared to increase over the course of the monitoring period. The average specific conductivity at Murry Pacific yard #1 was much higher than at other yards because one of the three discharges from this site (discharge #1, Appendix I) is tidally influenced.

Total suspended solids concentrations were variable both within and between yards. Concentrations ranged from 11 to 3,000 mg/L. Solids concentrations were much higher at Murry Pacific yard #2 and Wasser/Winters (average concentrations of 1,100 mg/L and 1,200 mg/L, respectively) than at Portac and Murry Pacific yard #1 (average concentrations of 84 mg/L and 39 mg/L, respectively). This is largely due to the fact that most of the runoff from Portac and Murry Pacific yard #1 enters low-gradient central ditches which act as settling basins, prior to discharge. Volatile and nonvolatile suspended solids analyses (Appendix I) showed that solids coming off the yards were composed of approximately equal proportions of organic and inorganic matter.

[1]Calculated using the formula:

$$CA = \frac{\sum_{i=1}^{n} (C_i Q_i)}{\sum_{i=1}^{n} Q_i}$$

where: C_A = flow-weighted concentration (hypothetical average concentration of constituent in discharge after complete mixing of all waste streams).
C_i = Concentration of constituent in discharge
Q_i - Flow of discharge

NOTE: Data deletions and values reported at less than detection limits were treated as zeros in the flow-weighting calculation. These data modifications resulted in calculation of conservative metals concentrations.

Table 8. **Conventional water quality parameters and metals concentrations in log sort yard runoff to Blair and Hylebos Waterways; WDOE data collected November 1983 - May 1984 (ug/L total metal).**

Sort Yard	Date	Time	Total Yard Flow (MGD)	pH (S.U.)	Specific Conductivity (umhos/cm)	Total Susp. Solids† (mg/L)	Arsenic†	Zinc†	Copper†	Lead†	Nickel†	Antimony†	Cadmium†
BLAIR WATERWAY													
Murry Pacific Yard #2	11/04/83	0800-0900	0.35	5.2	161	3,000	10,000	3,500	1,200	590	140	48	3.3
(total acreage = 50.8)	12/29/83	2105-2230	2.1	5.2	140	230	2,200	470	220*	160*	32	--	0.42
	03/12/84	1610-1755	0.31	5.8	120	1,700	7,600	1,500	900*	230	80	41	2.1
	04/10/84	1640-1730	0.11	5.9	120	390	7,600	1,900	130*	1,000*	110	52	2.3
	05/03/84	0950-1110	0.11	5.9	150	390	4,400	690	450	300	43	68	0.98
		Average	0.60	5.6	140	1,100	6,400	1,600	581*	460*	81	52	1.8
WAPATO CREEK/BLAIR WATERWAY													
Portac	11/04/83	1000-1030	0.36	5.7	910	110	2,900	5,000	1,400	290	270	140	10
(total acreage = 28.2)	12/29/83	2030-2045	1.8	5.8	230	28	1,100	790	310	9*	30	--	1.0
	03/12/84	1535-1555	0.11	6.1	600	130	7,100	2,600	1,600	570	130	380	3.5
	04/10/84	1440-1500	0.095	6.3	690	64	5,800	1,700	720	270	87	150	2.9
	05/03/84	1535-1550	0.058	6.4	930	88	9,500	2,100	1,000	380	120	120	2.0
		Average	0.48	5.1	670	84	5,300	2,400	1,000	300*	130	200	3.9
HYLEBOS WATERWAY													
Wasser/Winters	11/04/83	1030-1100	0.07	5.5	240	1,200	7,100	2,500	1,000	540	180	130	3.4
(total acreage = 11.7)	12/29/83	1845-1930	0.32	5.5	860	230	1,400	490	160*	130	20	--	0.8
	03/12/84	1810-1845	0.15	5.0	380	1,500	8,300	3,200	2,800*	1,600	140	100	5.2
	04/10/84	1510-1555	0.095	5.3	550	300	3,000	870	610*	390*	45	46*	1.3
	05/03/84	1250-1335	0.015	6.1	640	1,600	12,000	1,700	1,200	830	120	28	1.3
		Average	0.13	5.9	530	1,200	6,400	1,800	1,200*	700*	100	76*	2.4
Murry Pacific Yard #1	11/04/83	1120-1135	0.13	5.9	4,000	11	1,100	2,100	99*	--	44*	65	2.7
(total acreage = 18.0)	12/29/83	2000-2010	0.73	6.1	5,500	33	500	590	84*	67*	6	--	0.5
	03/12/84	1510-1525	0.057	6.4	2,000	72	2,700	1,500	312*	350	33	120	2.0
	04/10/84	1410-1425	0.042	6.7	1,600	39	3,400	1,400	410	330*	140	100	2.1
	05/03/84	1205-1220	0.023	6.8	4,000	43	1,300	1,200	150	270	37	72	0.9
		Average	0.28	6.4	3,400	39	1,800	1,400	210*	250*	52*	89	1.6
	Average of all discharges		0.37	6.0	1,200	610	4,800	1,800	750*	430*	91*	100*	2.4

-- = No data.
* = Blank corrected (see text under Quality Assurance).
† = Flow-weighted concentration.

High metals concentrations in runoff , especially arsenic, zinc, and copper, were characteristic of all four yards. The following ranges in concentrations were observed: arsenic, 500 - 12,000 ug/L; zinc, 470 - 5,000 ug/L; copper, 84 - 2,800 ug/L; lead, 9 - 1,600 ug/L; nickel, 6 - 270 ug/L; antimony, 28 - 380 ug/L; and cadmium, 0.42 - 10 ug/L. No single yard consistently had higher metals concentrations in its runoff than other yards. Runoff from Murry Pacific yard #1, however, clearly had the lowest metals concentrations.

Data on individual discharges at these four yards (Appendix I) show metals concentrations were highly variable. The highest metals concentrations were generally seen in discharges draining heavy traffic areas. The highest concentration discharges at each yard were as follows: Murry Pacific yard #2 - discharges #4, #6, #7, and #8; Portac - discharge #2; Wasser/Winters - discharge #1, and Murry Pacific #1 - discharges #2 and #3.

To assess the short-term variability in metals concentrations in sort yard runoff, one discharge was selected during each survey between December 1983 and May 1984 for replicate sampling. The range about the mean of three replicates each collected at four drains (Appendix I) was generally within ± 10 percent for arsenic, zinc, and copper, and ± 20 percent for lead, nickel, and cadmium. Antimony values ranged within ± 75 percent, which could be caused by the variable loss of volatile antimony compounds during sample digestion and reflux in the laboratory (Bailey, 1984).

Dissolved metals determinations for arsenic, zinc, copper, and lead were made on twenty runoff samples (see Table 9). Dissolved arsenic, zinc, and copper constituted a substantial portion of the total metal present in most samples. Lead was primarily in particulate form.

Table 9. Dissolved metals as a percentage of total metals in log sort yard runoff to Blair and Hylebos Waterways: WDOE data collected December 1983 - May 1984.

Sort Yard	Arsenic	Zinc	Copper	Lead
Murry Pacific Yard #2	$74(19\text{-}98)_8$	$36(3\text{-}78)_8$	$34(4\text{-}80)_3$	$18(6\text{-}45)_4$
Portac	$75(32\text{-}95)_4$	$75(56\text{-}85)_4$	$64(49\text{-}87)_3$	$31(29\text{-}33)_2$
Wasser/Winters	$58(50\text{-}75)_4$	$25(9\text{-}51)_3$	$4(4)_1$	$6(1\text{-}14)_3$
Murry Pacific Yard #1	$42(16\text{-}61)_4$	$74(51\text{-}96)_4$	$61(61)_1$	$3(3)_1$
Average	62	53	41	15

$\text{average(range)}_{\text{number of discharges}}$

A summary of data collected on the remaining eight sort yards during the initial reconnaissance survey and additional data collected in June 1984 is shown in Table 10. Metals and suspended solids are reported as flow-weighted concentrations for Louisiana Pacific and Weyerhaeuser because it was possible to measure all discharges at these yards. Only one discharge was measured at each of the remaining yards. Results for both conventional parameters and metals are generally comparable to data from the four intensively sampled yards. However, noteworthy exceptions are the Weyerhaeuser and St. Regis yards where metals concentrations were one to two orders of magnitude lower than any of the other yards. This is probably due to the fact that Weyerhauser's yard is completely paved as are the service roads at St. Regis which eliminates the need for the application of ballast materials in these areas. In addition, runoff from approximately one-half of the St. Regis yard passes through a settling pond prior to discharge. The differences seen in arsenic and zinc concentrations between samplings on December 12, 1983, and June 29, 1984, are not unusual when compared to the routine monitoring data.

The metals loads to Blair and Hylebos Waterways measured during routine monitoring at the Murry Pacific yards #1 and #2, Portac, and Wasser/Winters yards are in Table 11. Arsenic loads were the highest, ranging from 0.25 to 38 lbs/day; followed by zinc (0.21 to 15 lbs/day), copper (0.03 to 4.7 lbs/day), and lead (0.051 to 2.7 lbs/day). Nickel, antimony, and cadmium loads were generally one to two orders of magnitude lower than those measured for arsenic, zinc, and copper. The arsenic load from Murry Pacific's yard #2 was much higher than from other yards except for the May, 1984, collection during which Portac had the highest load.

Runoff and metals loads were also calculated per unit acre as shown in Table 12 to normalize comparison between yards. Acreages for each yard were determined using a compensating polar planimeter. The average flows measured at Murry Pacific yards #1 and #2 and Wasser/Winters compared very closely, 0.011 to 0.012 MGD/acre, indicating that most of the runoff was accounted for in the field work. A slightly higher average flow of 0.017 MGD/acre was measured at Portac--one of its discharges, a buried concrete pipe drain (discharge #1, Appendix I) may receive runoff from an adjacent lot. Metals loads per unit acre were also generally comparable between yards, being within a factor of four in most cases.

Since runoff measurements were limited or missing from most of the yards that were not intensively sampled, this required selection of a runoff coefficient in order to: (1) provide comparable (annual average) loading estimates for all yards, and (2) estimate the combined annual metals loading in runoff from all twelve yards.

Available literature on runoff coefficients (C) was reviewed to guide the selection of a credible value for C. Runoff coefficients for land uses generally equivalent to those encountered at the log sort yards are summarized in Appendix IV. Based on this review, a runoff coefficient of 0.40 was chosen. It is

Table 10. Conventional water quality parameters and metals data on runoff to Commencement Bay waterways; from log sort yards other than Murry Pacific Yard #2, Portac, Wasser/Winters, and Murry Pacific Yard #1, collected by WDOE November 1983 to June 1984.

Sort Yard	Date	Time	Flow (MGD)	pH (S.U.)	Specific Conductivity (umhos/cm)	Total Suspended Solids (mg/L)	Arsenic (ug/L, total metal)	Zinc	Copper	Lead	Nickel	Antimony	Cadmium
Hylebos Waterway													
Cascade Timber Yard #1	12/12/83	1215	0.003 1/	7.3	247	270	7,280	3,000	695	710	188	71	4.2
" " " "	06/29/84	1400	--	5.7	265	110	1,970	1,685	148	36	56	105	3
(total acreage = 6.6)													
Cascade Timber Yard #2	12/12/83	1015	0.005 1/	7.3	841	27	122	--	--	--	22	1u	16
" " " "	06/29/84	1115	0.065 1/	5.9	437	7,800	4,940	5,340	4,000	2,470	325	155	0.2u
(total acreage = 13.5)													
Dunlap Towing	11/04/83	1200	--	--	--	--	3,800	1,425	183	267	--	91	3.4
" "	06/29/84	1130	--	7.5	1,380	72	2,680	315	342	171	27	259	0.8
(total acreage = 16.6)													
Louisiana Pacific	12/12/83	1120-1150	0.06 2/	(6.8-7.1)	(492-951)	430(52-1,000)†	1,980†	500†	410†	310†	110†	67†	1.2†
" "	06/29/84	1230-1300	0.66 2/	(6.8-7.3)	(307-2,270)	120(40-310)†	850†	170†	73†	17†	13†	5.3†	0.15*†
(total acreage = 18.3)													
Weyerhaeuser	01/05/84	1400-1410	0.024 2/	(4.6-5.8)	(345-480)	740(650-1,200)†	32†	240†	--	--	47†	3.7†	0.4†
"	06/29/84	1140-1200	0.086 2/	(4.9-5.3)	(184-216)	1,500(1,400-1,700)†	44†	650†	121†	35†	69†	0.26*†	1.9†
(total acreage = 23.3)													
Puyallup Waterway													
McFarland Cascade	11/04/83	1310	0.15 1/	5.6	511	150	250	445	--	--	73	--	1.4
" "	06/29/84	1040	0.38 1/	6.3	144	160	1,115	225	171	33	13	14	0.2
(total acreage = 14.1)													
Sitcum Waterway													
Cascade Timber Yard #3	12/12/83	1400	0.11 1/	6.9	841	200	156	102	--	--	18	1u	0.2u
" " " "	06/29/84	1100	--	6.7	248	210	1,750	293	138	69	17	8	0.5
(total acreage = 20.4)													
St. Paul Waterway													
St. Regis Sort Yard (total acreage = 56.4)	06/29/84	1020	0.026 1/	6.6	521	260	25	97	65	17	7	2	0.4

1/ = Flow of individual discharge only; total yard flow not determined
2/ = Total yard flow
† = Flow-weighted concentration(range)
u = Not detected at detection limit shown
-- = No data
* = Blank corrected (see text under Quality Assurance)

Table 11. Metals loads from log sort yard runoff to Blair and Hylebos Waterways; WDOE data collected November 1983 - May 1984 (pounds/day total metal).

Sort Yard	Date	Total Yard Flow (MGD)	Arsenic	Zirc	Copper	Lead	Nickel	Antimony	Cadmium
BLAIR WATERWAY									
Murry Pacific Yard #2	11/04/83	0.35	32	11	3.9	1.9	0.44	0.15	0.01
	12/29/83	2.1	38	8.2	4.0*	2.7*	0.38	--	0.0074
	03/12/84	0.31	20	3.9	2.3*	1.9	0.21	0.11	0.0055
	04/10/84	0.11	6.9	1.7	1.0	0.92*	0.11	0.047	0.0021
	05/03/84	0.11	4.0	0.63	0.42	0.28	0.04	0.022	0.0009
	Average	0.60	20	5.1	2.3*	1.5*	0.24	0.082	0.0052
WAPATO CREEK/BLAIR WATERWAY									
Portac	11/04/83	0.36	8.8	15	4.2	0.86	0.81	0.43	0.031
	12/29/83	1.8	9.2	12.0	4.7	0.13*	0.45	--	0.014
	03/12/84	0.11	6.5	2.4	1.5	0.53	0.12	0.35	0.0034
	04/10/84	0.095	4.7	1.3	0.57	0.22	0.069	0.12	0.003
	05/03/84	0.058	4.6	1.0	0.49	0.18	0.059	0.057	0.001
	Average	0.48	6.8	6.3	2.3	0.38*	0.30	0.24	0.0054
HYLEBOS WATERWAY									
Wasser/Winters	11/04/83	0.07	4.1	1.5	0.59	0.32	0.10	0.073	0.002
	12/29/83	0.32	3.8	1.3	0.44*	0.36*	0.052	--	0.002
	03/12/84	0.15	10.4	4.0	3.5*	2.0	0.18	0.13	0.0065
	04/10/84	0.095	2.4	0.69	0.48	0.31*	0.026	0.036*	0.0011
	05/03/84	0.015	1.5	0.21	0.15	0.10	0.015	0.0035	0.00016
	Average	0.13	4.4	1.5	1.0*	0.62*	0.075	0.061*	0.0024
Murry Pacific Yard #1	11/04/83	0.13	1.2	2.2	0.11*	--	0.048*	0.07	0.0029
	12/29/83	0.73	3.1	3.7	0.51*	0.41*	0.038	--	0.0032
	03/12/84	0.057	1.3	0.74	0.20*	0.17	0.016	0.059	0.00092
	04/10/84	0.042	1.2	0.47	0.15*	0.12*	0.050	0.037	0.00074
	05/03/84	0.023	0.25	0.23	0.03	0.051	0.0072	0.014	0.00018
	Average	0.20	1.4	1.5	0.20*	0.19*	0.032*	0.045	0.0016

-- = no data
* = Blank corrected (see text under Quality Assurance)

Table 12. Metals loads per acre from log sort yard runoff to Blair and Hylebos Waterways; WDOE data collected November 1983 - May 1984 (pounds/acre total metal).

Sort Yard	Date	Total Yard Flow (MGD/acre)	Arsenic	Zinc	Copper	Lead	Nickel	Antimony	Cadmium
BLAIR WATERWAY									
Murry Pacific Yard #2	11/04/83	0.0069	0.63	0.22	0.077	0.037	0.0087	0.0030	0.0002
(total acreage = 50.8)	12/29/83	0.041	0.75	0.16	0.079*	0.053*	0.0075	--	0.00015
	03/12/84	0.0061	0.39	0.077	0.045*	0.037	0.0041	0.0022	0.00011
	04/10/84	0.0022	0.14	0.033	0.020	0.018*	0.0022	0.00093	0.00004
	05/03/84	0.0022	0.079	0.012	0.0083	0.0055	0.00079	0.00043	0.000018
	Average	0.012	0.40	0.10	0.046*	0.030*	0.0047	0.0016	0.0001
WAPATO CREEK/BLAIR WATERWAY									
Portac	11/04/83	0.013	0.31	0.53	0.15	0.030	0.029	0.015	0.0011
(total acreage = 28.2)	12/29/83	0.064	0.33	0.43	0.17	0.0046*	0.016	--	0.0005
	03/12/84	0.0039	0.23	0.085	0.053	0.019	0.0043	0.012	0.00012
	04/10/84	0.0034	0.17	0.046	0.020	0.0078	0.0024	0.0043	0.00011
	05/03/84	0.0021	0.16	0.035	0.017	0.0064	0.0021	0.002	0.000035
	Average	0.017	0.24	0.23	0.082	0.014*	0.011	0.0083	0.00037
HYLEBOS WATERWAY									
Wasser/Winters	11/04/83	0.006	0.35	0.13	0.050	0.027	0.0085	0.0062	0.00017
(total acreage = 11.7)	12/29/83	0.027	0.32	0.11	0.038*	0.031*	0.0044	--	0.00017
	03/12/84	0.013	0.89	0.34	0.30*	0.17	0.015	0.011	0.00056
	04/10/84	0.0081	0.21	0.059	0.41	0.026*	0.0022	0.0031*	0.000094
	05/03/84	0.0013	0.13	0.018	0.13	0.0085	0.0013	0.0003	0.000014
	Average	0.011	0.38	0.13	0.19*	0.053*	0.0063	0.0052*	0.0002
Murry Pacific Yard #1	11/04/83	0.0072	0.067	0.12	0.0061*	--	0.0027*	0.0039	0.00016
(total acreage = 18.0)	12/29/83	0.041	0.17	0.21	0.028*	0.023*	0.0021	--	0.00018
	03/12/84	0.0032	0.072	0.041	0.011*	0.0094	0.00089	0.0033	0.000051
	04/10/84	0.0023	0.067	0.026	0.0083*	0.0067*	0.0028	0.0021	0.000041
	05/03/84	0.0013	0.014	0.013	0.0017	0.0028	0.0004	0.00078	0.00001
	Average	0.011	0.078	0.082	0.011*	0.010*	0.0018*	0.0025	0.000088

-- = no data
* = Blank corrected (see text under Quality Assurance)

recognized that C may vary substantially in response to a number of variables including variations in rainfall intensity, antecedent soil moisture conditions, soil type, and the specific operational characteristics of each yard. Although 0.40 represents our best estimate of C, C may well vary from 0.2 to 0.6 at individual yards during individual rainfall events. There is a degree of uncertainty in the choice of any runoff coefficient, and care should be exercised when using the annual average metals loads generated using C.

Daily mass loadings from each yard were then calculated using the concentration data in Tables 8 and 9, yard acreages in Tables 10 and 12, and application of the 0.40 runoff coefficient to an annual rainfall for Tacoma of 37.2 inches from the 30-year period of record (Table 13). Estimated average annual daily metals loads in runoff from the sort yards are shown in Table 14. Because Table 14 is intended to estimate metals loads from runoff on an annual basis, it substantially underestimates short-term loading rates during storm events. The estimated average annual metals loads in surface runoff from all twelve log sort yards combined to Commencement Bay waterways in pounds/year are as follows: arsenic, 2,500; zinc, 1,100; copper, 510; lead, 310; nickel, 66; antimony, 50; and cadmium 2.0.

Table 13. Monthly average rainfall data (inches) for Tacoma, Washington, (months where log sort yards sampled underlined).

Location	Tacoma Central Treatment Plant #1[1]				Tacoma City Hall[2]	
Period of Record	1983-1984[3]	Percent of Annual Rainfall	1982-1984	Percent of Annual Rainfall	1951-1980	Percent of Annual Rainfall
July	2.76	6	1.14	3	0.75	2
August	1.92	4	0.85	2	1.25	3
September	1.84	4	1.59	4	1.95	5
October	1.40	3	2.74*	7	3.27	9
November	8.62	19	6.85*	16	5.47	15
<u>December</u>	5.38	12	6.38*	15	6.02	16
<u>January</u>	4.65	10	5.92	14	5.74	15
February	3.39	7	5.45	13	4.06	11
<u>March</u>	4.29	9	4.25	10	3.38	9
<u>April</u>	2.57	6	2.07	5	2.49	7
<u>May</u>	4.42	10	2.00	5	1.48	4
<u>June</u>	4.15	9	2.41	6	1.31	4
Average Annual	45.4		41.7		37.2	

[1]data provided by Raymond Redding, Tacoma Central Treatment Plant #1.
[2]data provided by Howard Critchfield, Washington State Climatologist, WWU.
[3]study period.

*1984 data not included.

Table 14. Estimated average annual daily metals loads in runoff from Tacoma tideflats log sort yards. Based on average annual rainfall of 37.2 inches and a runoff coefficient of 0.40.

Sort Yard	Total Average Annual Daily Runoff (MGD)	(lbs/day total metal) Arsenic	Zinc	Copper	Lead	Nickel	Antimony	Cadmium	Total Suspended Solids (lbs/day)
HYLEBOS WATERWAY									
Wasser/Winters	0.013	0.69	0.20	0.13*	0.075*	0.011	0.0082*	0.00026	130
Murry Pacific Yard #1	0.020	0.30	0.23	0.035*	0.042*	0.0087*	0.0015	0.00027	6.5
Cascade Timber yard #1	0.0072	0.28	0.14	0.025	0.022	0.0073	0.0053	0.00022	11
Cascade Timber yard #2	0.015	0.32	0.67	0.50	0.31	0.022	0.0098	0.001	490
Dunlap Towing	0.018	0.49	0.13	0.04	0.033	0.0041	0.026	0.00032	11
Louisiana Pacific	0.020	0.24	0.056	0.040	0.027	0.01	0.006	0.00011	46
Weyerhaeuser1/	0.063	0.02	0.23	0.064	0.018	0.031	0.0011*	0.0012	590
BLAIR WATERWAY									
Murry Pacific Yard #2	0.055	2.9	0.73	0.27*	0.21*	0.037	0.024	0.00083	500
Portac	0.031	1.4	0.62	0.26	0.078*	0.034	0.052	0.001	22
PUYALLUP WATERWAY									
McFarland Cascade	0.015	0.086	0.042	0.021	0.0041	0.0054	0.0018	0.0001	19
SITCUM WATERWAY									
Cascade Timber Yard #3	0.022	0.18	0.036	0.025	0.013	0.0033	0.00073	0.000046	38
ST. PAUL WATERWAY									
St. Regis Sort yard	0.061	0.013	0.049	0.033	0.0087	0.0036	0.001	0.0002	130
Total Daily Load (lbs/day)		6.9	3.1	1.4	0.84	0.18	0.14	0.0056	2,000
Total Annual Load (lbs/year)		2,500	1,100	510	310	66	50	2.0	730,000

* = Blank corrected (see text under Quality Assurance)

1/Paved yard, runoff assumed to be 100 percent

Groundwater discharge to the waterways was not considered here but, in light of the fact that surface runoff from the log sort yards was estimated to be 40 percent of rainfall and a shallow groundwater table is present in the tideflats area, a strong potential exists that groundwater in the vicinity of the sort yards is being contaminated with metals. Therefore, groundwater flux may be a major mechanism by which metals are being transported to the waterways.

Table 15 presents a relative ranking of the Tacoma tideflats log sort yards based on the loadings presented in Table 14 for arsenic, zinc, copper, and lead. For arsenic, copper, and lead, four yards consistently have the highest loads. They are; Murry Pacific's yard #2, Cascade Timber's yard #2, Portac, and Wasser/ Winters. Three of these yards--Murry Pacific's yard #2, Cascade Timber's yard #2, and Portac--also have the highest zinc load. Weyerhaeuser's yard ranks near the top for zinc and copper; but this is because a runoff coefficient of 1.0 was assumed for this paved yard. Metals concentrations in runoff from the Weyerhaeuser yard were among the lowest measured in the survey.

Table 15. Ranking of Tacoma tideflats log sort yards based on estimated average annual daily metals loads for arsenic, zinc, copper, and lead (lbs/day).

Sort Yard	Arsenic	Sort Yard	Zinc
Murry Pacific Yard #2	2.9	Murry Pacific Yard #2	0.73
Portac	1.4	Cascade Timber Yard #2	0.67
Wasser/Winters	0.69	Portac	0.62
Dunlap Towing	0.49	Weyerhaeuser†	0.23
Murry Pacific Yard #1	0.30	Murry Pacific Yard #1	0.23
Cascade Timber Yard #2	0.32	Wasser/Winters	0.20
" " " #1	0.28	Cascade Timber Yard #1	0.14
Louisiana Pacific	0.24	Dunlap Towing	0.13
Cascade Timber Yard #3	0.18	Louisiana Pacific	0.056
McFarland Cascade	0.086	St. Regis Sort Yard	0.049
Weyerhaeuser†	0.02	McFarland Cascade	0.042
St. Regis Sort Yard	0.013	Cascade Timber Yard #3	0.036
	Copper		**Lead**
Cascade Timber Yard #2	0.50	Cascade Timber Yard #2	0.31
Murry Pacific Yard #2	0.20*	Murry Pacific Yard #2	0.21
Portac	0.26	Portac	0.078*
Wasser/Winters	0.13*	Wasser/Winters	0.075*
Weyerhaeuser†	0.064	Murry Pacific Yard #1	0.042*
Dunlap Towing	0.04	Dunlap Towing	0.033
Louisiana Pacific	0.04	Louisiana Pacific	0.027
Murry Pacific Yard #1	0.035*	Cascade Timber Yard #1	0.022
St. Regis Sort Yard	0.033	Weyerhaeuser†	0.018
Cascade Timber Yard #1	0.025	Cascade Timber Yard #3	0.013
" " " #3	0.025	St. Regis Sort Yard	0.0087
McFarland Cascade	0.021	McFarland Cascade	0.0041

†Paved yard, runoff assumed to be 100 percent.
*Blank-corrected (see text under Quality Assurance).

To assess the relative importance of the log sort yards as arsenic sources to Blair and Hylebos Waterways, the average arsenic loads in sort yard runoff measured during storm events are compared in Table 16 to arsenic loads from nine major discharges to Blair and Hyleobs Waterways monitored by WDOE between April 1981 and September 1984. Also included are the estimated annual daily arsenic loads (Table 14) for the sort yards. Murry Pacific yard #2 and Portac had average measured arsenic loads of 20 lbs/day and 6.8 lbs/day, respectively. Their estimated annual daily arsenic loads were approximately one order of magnitude lower (2.9 lbs/day and 1.4 lb/day, respectively). The large difference between these loads indicates that arsenic loadings for the sort yards are the greatest during storm events. Arsenic loads from other non-sort yard discharges to Blair Waterway shown in Table 16 are typically 1 lb/day or less. Therefore, during storm events, these two sort yards are the major arsenic sources to Blair Waterway. In Hylebos Waterway, four discharges have arsenic loads of 1 lb/day or greater. They are in decreasing order, Wasser/Winters - 4.4 lbs/day; Hylebos Creek - 4.0 lbs/day; Pennwalt's final process effluent - 3.9 lbs/day; and Murry Pacific sort yard #1 - 1.4 lbs/day. Estimated annual daily arsenic loads for Wasser/Winters and Murry Pacific yard #1 (0.69 lb/day and 0.30 lb/day, respectively) were also roughly an order of magnitude less than their storm-event loadings. The load from Pennwalt's final process effluent (3.9 lbs/day), while based on a single measurement, is probably real. Data reported by Pennwalt in their consolidated permit show a net effluent load of 2.5 lbs/day. Since most sort yard runoff primarily occurs during winter storm events, during these periods the log sort yards are probably the major source of arsenic to Hylebos Waterway. However, it is likely that Hylebos Creek constitutes the largest arsenic load to the waterway during periods of light precipitation in the winter and for most of the remaining parts of the year. In addition, based on limited data, it appears that Pennwalt's effluent may be the largest arsenic source to Hylebos Waterway during periods of reduced flow (less than 10 MGD) in Hylebos Creek (Johnson and Norton, 1984).

Table 16. Arsenic loads (lbs/day) in major discharges to Hylebos and Blair Waterways calculated from WDOE data collected April 1981 - September 1984.

Discharge	Date(s)	Measured Loads Average	Measured Loads Range	Number of Observations	Estimated Annual Daily Loads[1/]
BLAIR WATERWAY					
Murry Pacific Yard #2	11/04/83-05/03/84	20	4.4 - 38	5	2.9
Portac	11/04/83-05/03/84	6.8	4.6 - 9.2	5	1.4
Lincoln Drain North Shore	04/21/81-05/30/84	1.2	0.65 - 1.9	3	--
Lincoln Drain South Shore[2]	10/12/83-05/03/84	1.0	0.10; 1.9	2	--
South corner Turning basin drain	08/17/81-05/30/84	0.30	0.043 - 0.43	4	--
Wapato Creek[3]	10/12/83-05/03/84	0.039	0.0074; 0.071	2	--
HYLEBOS WATERWAY					
Wasser/Winters sort yard	11/04/83-05/03/84	4.4	1.5 - 10.4	5	0.69
Hylebos Creek[4]	08/17/81-09/05/84	4.0	ND - 13.0	14	--
Pennwalt Process effluent	06/2-3/81	3.9	--	1	--
Murry Pacific Yard #1	11/04/83-05/03/84	1.4	0.25 - 3.1	5	0.30
Kaiser Ditch	08/17/81-04/17/84	0.56	ND - 1.9	8	--
Morningside Drain	08/17/81-11/08/83	0.047	0.008 - 0.13	4	--
Lincoln Avenue Drain	04/28/82-05/30/84	0.0097	0.009 - 0.011	3	--

ND = Not detected
-- = No data
1/ = From Table 14
2/ = Upstream of Murry Pacific yard #2
3/ = Upstream of Portac
4/ = Upstream of Wasser/Winters

Receiving Environment

The results from analysis of surface water samples collected May 3, 1984, in Blair and Hylebos Waterways are shown in Table 17.

pH in the waterways was between 7.1 and 7.8. Salinity ranged from 4.7 to 26 o/oo with lower salinities being near the major freshwater inputs--Wapato Creek, South Lincoln Avenue ditch, Blair Waterway mouth (probably due to the Puyallup River plume) and Hylebos Creek. Total suspended solids concentrations ranged from 18 to 110 mg/L and were also highest near the above-mentioned freshwater inputs.

Arsenic, zinc, and copper were present in higher and more variable concentrations than other metals. Concentration ranges were 1u to 120 ug/L (arsenic), 1u to 155 ug/L (zinc), and 12 to 54 ug/L (copper). Lead concentrations were generally consistent throughout both waterways, ranging from 6 to 22 ug/L. Nickel, antimony, and cadmium concentrations were low in almost all samples.

The arsenic, zinc, and copper data are plotted in Figures 5 and 6 to show their longitudinal distribution within Blair and Hylebos Waterways. In Blair Waterway (Figure 5), substantial concentration gradients existed for arsenic, zinc, and copper. A primary peak in concentration occurred at approximately mid-waterway near Murry Pacific yard #2 and South Lincoln Avenue ditch. Approximately 70 percent of Murry Pacific yard #2 runoff reaches Blair Waterway via discharge to South Lincoln Avenue ditch. As previously shown in Table 16, the arsenic load from Murry Pacific yard #2 is approximately an order of magnitude larger than that from the South Lincoln Avenue ditch. A secondary peak occurred at the head of the waterway near the mouth of Wapato Creek. Arsenic concentrations in nearshore samples off Murry Pacific yard #2 and South Lincoln Avenue ditch were substantially higher than in samples collected farther offshore. A similar gradient (i.e., nearshore versus offshore) was not observed for zinc or copper. The source of the secondary peak in metals is evident from the Wapato Creek data. Substantial increases in arsenic, zinc, and copper concentrations (also lead and suspended solids [Table 17]) occurred between stations above and below Portac discharges. This was especially true for arsenic which increased by a factor of 35 in Wapato Creek after passing Portac.

Longitudinal concentration gradients for arsenic, zinc, and copper in Hylebos Waterway (Figure 6) were not as marked as those in Blair. Arsenic and zinc concentrations gradually increased moving toward the head of the waterway. A similar trend was not observed for copper. Nearshore samples at Murry Pacific yard #1 and Wasser/Winters had higher concentrations of arsenic and zinc than nearby mid-channel samples. Copper also appeared elevated near Wasser/Winters, but not at Murry Pacific yard #1.

Table 17. Conventional parameters and metals concentrations in water samples collected by WDOE from Blair and Hylebos Waterways and Wapato and Hylebos Creeks, May 3, 1984.

Sample Number	Station Number	Time Sampled	pH (S.U.)	Specific Conductivity (umhos/cm)	Salinity (o/oo)	Total Suspended Solids (mg/L)	Metals (ug/L total metal) Arsenic	Zinc	Copper	Lead	Nickel	Antimony	Cadmium
BLAIR WATERWAY													
14-1940	B-1	0930	7.3	--	15	24	16	23	24	12	1u	1u	0.6
14-1941	B-2	0935	7.7	--	25	18	13	17	12	6	--	--	--
14-1942	B-3	0940	7.8	--	26	23	1u	1u	18	13	--	--	--
14-1943	B-4	0945	7.8	--	25	20	13	10	15	8	1u	1u	0.6
14-1944	B-5	0950	7.7	--	26	20	40	15	21	11	1u	1u	0.3
14-1945	B-6	1000	7.6	--	23	24	88	35	31	9	1u	1u	0.4
14-1946	B-7	1005	7.8	--	25	19	8	14	22	7	--	--	--
14-1947	B-8	1010	7.4	--	20	21	59	87	54	8	--	--	--
14-1948	B-9	1020	7.3	--	16	34	120	72	30	12	1u	5	0.4
14-1949	B-10	1030	7.4	--	22	18	34	33	27	12	--	--	--
14-1950	B-11	1040	7.8	--	25	18	6	12	17	6	--	--	--
14-1951	B-12	1100	7.8	--	15	27	3	8	31	9	--	--	--
WAPATO CREEK													
14-1965	W-1	1445	7.4	220	--	32	2	8	14	4	1u	1u	0.4
14-1966	W-2	1130	7.1	2,720	--	58	70	65	34	11	1u	1u	0.2
HYLEBOS WATERWAY													
14-1952	H-1	1255	7.3	--	5.0	74	37	36	24	13	1u	1u	0.1u
14-1954	H-2	1250	7.1	--	5.4	71	56	56	49	20	1u	6	0.1
14-1955	H-3	1245	7.2	--	4.7	110	48	54	44	18	1u	4	0.3
14-1956	H-4	1240	7.4	--	15	24	13	24	19	8	--	--	--
14-1957	H-5	1235	7.5	--	18	26	18	27	28	11	--	--	--
14-1958	H-6	1230	7.5	--	18	24	18	19	23	8	--	--	--
14-1959	H-7	1210	7.4	--	19	26	68	32	20	8	1u	1u	0.1
14-1960	H-8	1215	7.5	--	22	28	38	36	21	10	1u	1u	0.3
14-1961	H-9	1220	7.5	--	12	44	80	155	45	22	1u	16	0.5
14-1962	H-10	1200	7.5	--	21	26	15	7	21	8	--	--	--
14-1963	H-11	1155	7.6	--	23	26	18	10	20	7	--	--	--
14-1964	H-12	1150	7.8	--	22	26	8	1u	31	10	--	--	--
HYLEBOS CREEK													
14-1907	HC-1	1300	7.1	318	--	31	12	7	21	11	1u	1u	0.1
14-1953	HC-2	1345	7.4	494	--	100	45	64	50	21	1u	3	0.1
EPA CRITERIA - SALTWATER AQUATIC LIFE1/													
24-hour average (chronic)							--	58	4	25	7.1	--	4.5
maximum (acute)							508	170	23	668	140	--	5.9

u = Not detected at detection limit shown
-- = Not analyzed
1/ = "EPA water quality criteria documents; availability," Federal Register, 1980

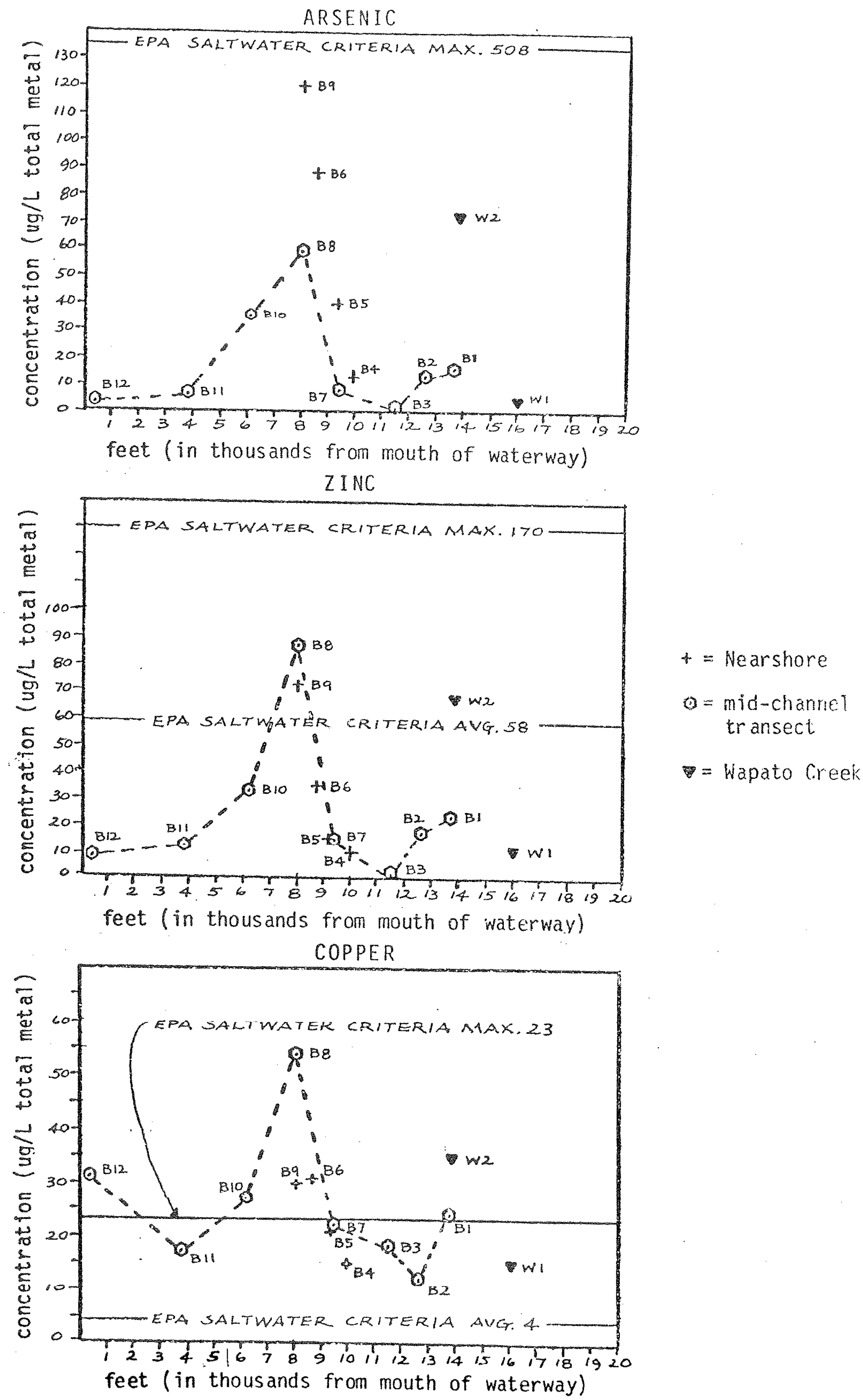


Figure 5. Arsenic, zinc, and copper concentrations in Blair Waterway and Wapato Creek surface water samples collected by WDOE May 3, 1984.

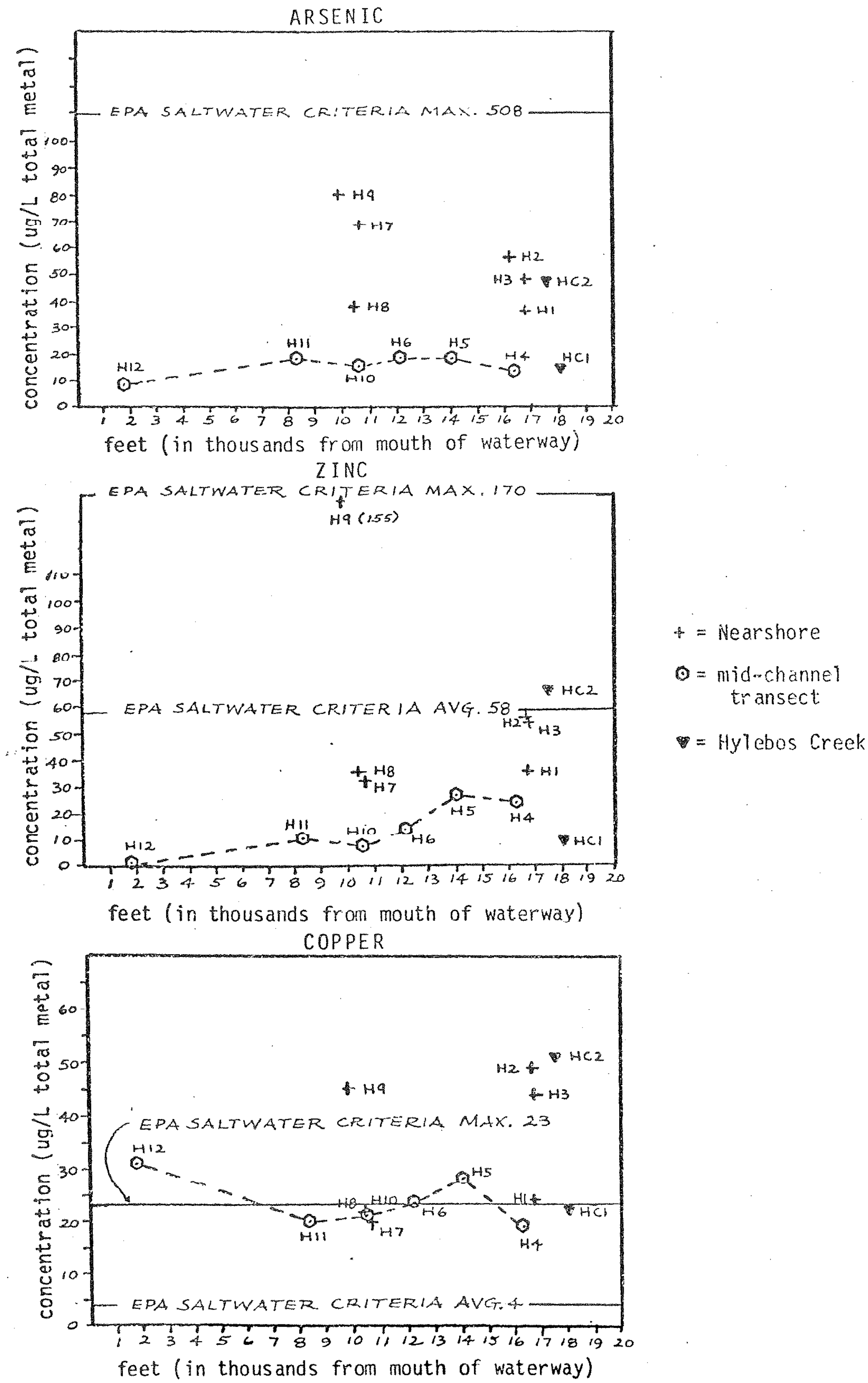


Figure 6. Arsenic, zinc, and copper concentrations in Blair Waterway and Hylebos Creek surface water samples collected by WDOE May 3, 1984.

In both Blair and Hylebos Waterways, violations of EPA criteria for the protection of saltwater aquatic life shown in Table 17 were seen for zinc and copper. In Blair Waterway, zinc values exceeded EPA chronic criteria in the vicinity of Murry Pacific yard #2 and South Lincoln Avenue ditch. The only zinc violation seen in Hylebos Waterway was nearshore by discharge #3 at Murry Pacific yard #1. This was also the highest concentration (155 ug/L) seen in either waterway during the present survey. EPA chronic criteria for copper was exceeded in all receiving water samples in both waterways. Sporadic violations of acute criteria values were also seen in both waterways. These occurred primarily near Murry Pacific yard #2 and South Lincoln Avenue ditch, at the mouth of Blair Waterway, and Hylebos Waterway at the mouth and again nearshore at both Wasser/Winters and Murry Pacific yard #1.

Locally toxic conditions for aquatic organisms could exist in nearshore receiving waters until sort yard runoff is completely mixed in the receiving waters. Comparison of metals concentrations in sort yard runoff (from Table 8) to the EPA water quality criteria indicates that arsenic and zinc would require approximately a 2- to 29-fold dilution in uncontaminated receiving waters, while copper would need anywhere from a 4- to 120-fold dilution to meet acute criteria levels. Because receiving waters appear to initially contain substantial concentrations of copper, much more dilution would be required to meet the criteria. A 3:1 dilution is needed to bring lead and nickel within criteria limits. Little or no dilution would be required for cadmium to meet EPA criteria. Generally speaking, dissolved metals exhibit a higher degree of toxicity to aquatic organisms than metals associated with particulates since they are not bound and therefore readily available for uptake. A high portion of the arsenic, zinc, and copper present in runoff was in the dissolved form.

While no protection criteria exist for suspended solids, the high concentrations of solids in sort yard runoff could have an adverse effect on organisms in the nearshore sort yard environment due to siltation.

The results of sediment samples analyses for Blair and Hylebos Waterways are presented in Table 18. Nearshore sediments in Blair Waterway off Murry Pacific sort yard #2 had a higher sand and lower organic carbon content than adjacent offshore sediments. Nearshore and offshore sediments were similar in percent nitrogen. In Hylebos Waterway, organic carbon, nitrogen, and grain size were similar in nearshore and offshore sediments except at Murry Pacific Yard #1 which had higher organic carbon in nearshore samples.

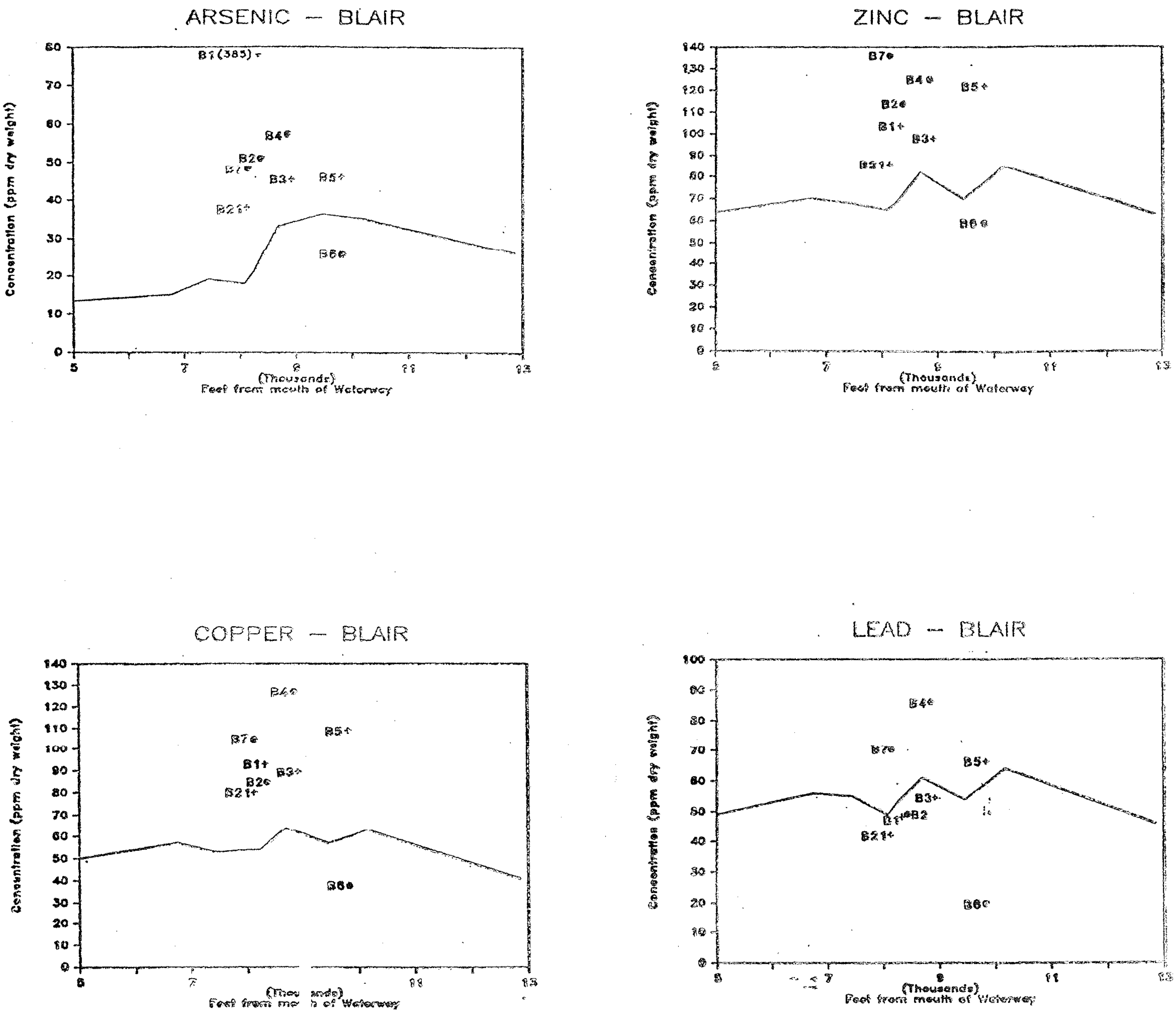
Figures 7 and 8 compare the metals data in Table 18 to results from mid-channel transects sampled in Blair and Hylebos Waterways on March 11-18, 1984, by Tetra Tech, Inc. as part of the Commencement Bay Superfund Investigations.†

†Data supplied by T. Ginn and R. Barrick, Tetra Tech, Inc.; Figures prepared by R. Feins, Tetra Tech, Inc.

Table 18. Conventional parameters and metals concentrations in sediment samples collected by WDOE from Blair and Hylebos Waterways near log sort yards, June 14, 1984.

Sample Number	Station Number	Position	Depth at MLLW (ft)	Moisture (%)	Total Organic Carbon (%)	Nitrogen (%)	Grain Size Sand (%)	Grain Size Silt (%)	Grain Size Clay (%)	Grain Size Total (%)	Metals (mg/Kg dry weight) Arsenic	Zinc	Copper	Lead	Nickel	Antimony	Cadmium
BLAIR WATERWAY																	
Murry Pacific Yard #2																	
14-2699	B-7	nearshore	34	46	2.4	0.33	20.6	61.3	18.2	100	48	131	106	68	15	0.6	0.50
14-2700	B-7(dup)	"	34	35	2.6	0.28	21.6	59.7	18.7	100	50	140	104	72	15	0.5	0.43
14-2694	B-2	"	29	49	2.5	0.22	26.7	58.3	15.1	100	51	114	85	49	12	0.3	0.23
14-2696	B-4	"	29	55	2.1	0.14	42.1	44.3	13.6	100	57	125	127	86	10	4.0	0.23
14-2698	B-6	"	27	71	0.65	0.04*	73.1	21.0	2.2	96.4	26	59	38	20	9	0.6	0.19
14-2701	B-21	offshore	41	53	1.2	0.22	17.4	64.3	18.2	100	38	86	80	42	15	0.2	0.22
14-2693	B-1	"	40	48	1.5	0.17	12.0	66.5	21.6	100	39	104	93	48	16	0.1u	0.23
14-2695	B-3	"	44	47	1.4	0.13	9.39	67.5	23.1	100	45	98	90	55	14	0.2	0.21
14-2697	B-5	"	45	44	1.8	0.30	7.7	72.8	29.4	100	46	122	109	66	15	0.5	0.27
WAPATO CREEK																	
Portac																	
14-2710	W-8	above	--	69	0.68	0.04*	81.1	16.3	0.89	98.3	14	70	23	14	7.3	0.1	0.04
14-2711	W-10	below	--	76	0.32	0.02*	91.7	7.2	--	98.9	45	78	23	10	6.2	0.1u	0.16
HYLEBOS WATERWAY																	
Murry Pacific Yard #1																	
17-2702	H-11	nearshore	10	33	5.6	0.20	58.1	31.5	10.5	100	116	293	192	134	28	1.8	0.73
14-2704	H-13	"	16	35	4.6	0.15	39.3	46.4	14.3	100	88	251	173	140	27	1.5	0.62
14-2703	H-12	offshore	27	50	2.7	0.09*	29.3	48.9	21.9	100	50	151	138	97	27	0.6	0.44
14-2705	H-14	"	28	54	2.5	0.27	51.5	33.3	15.2	100	30	129	90	63	20	0.5	0.24
Wasser/Winters																	
14-2706	H-16	nearshore	28	35	6.6	0.20	15.4	61.8	22.8	100	111	349	181	105	30	1.2	0.60
14-2708	H-18	"	28	34	6.3	0.19	13.4	58.1	28.4	100	150	282	201	110	32	1.5	0.84
14-2707	H-17	offshore	30	36	6.1	0.23	16.1	57.9	26.0	100	165	274	193	134	32	1.9	0.50
14-2709	H-19	"	28	37	5.9	0.19	12.6	61.1	26.4	100	184	276	206	112	34	1.5	0.51

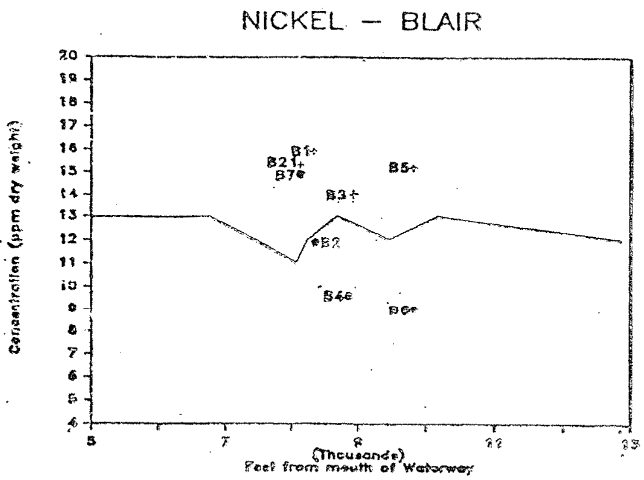
* = estimated concentration
u = not detected at detection limit shown

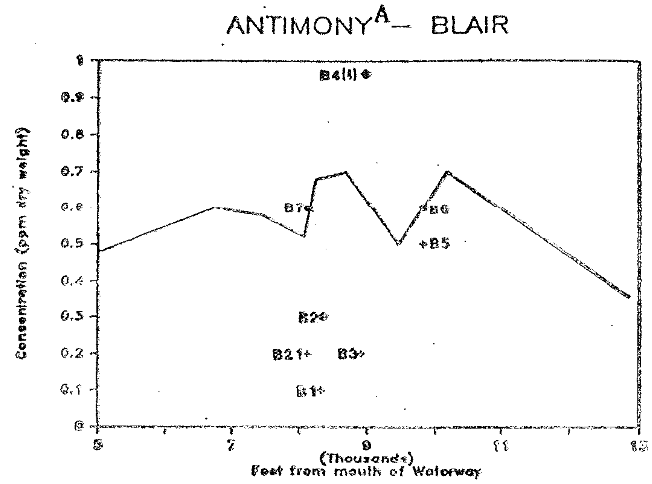


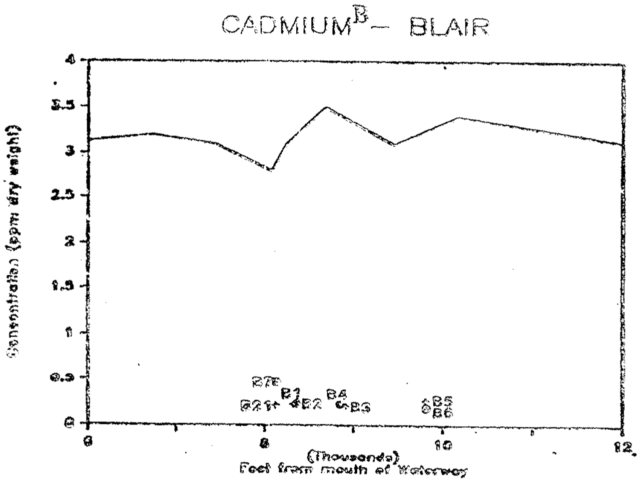
● Nearshore
\+ Offshore = WDOE station

Solid line = Tetra Tech mid-channel transect

Figure 7. Comparison of metals concentrations in Blair Waterway subtidal sediments off Murry Pacific yard #2 collected June 14, 1984, by WDOE to a mid-channel transect sampled March 11-18, 1984, by Tetra Tech, Inc.







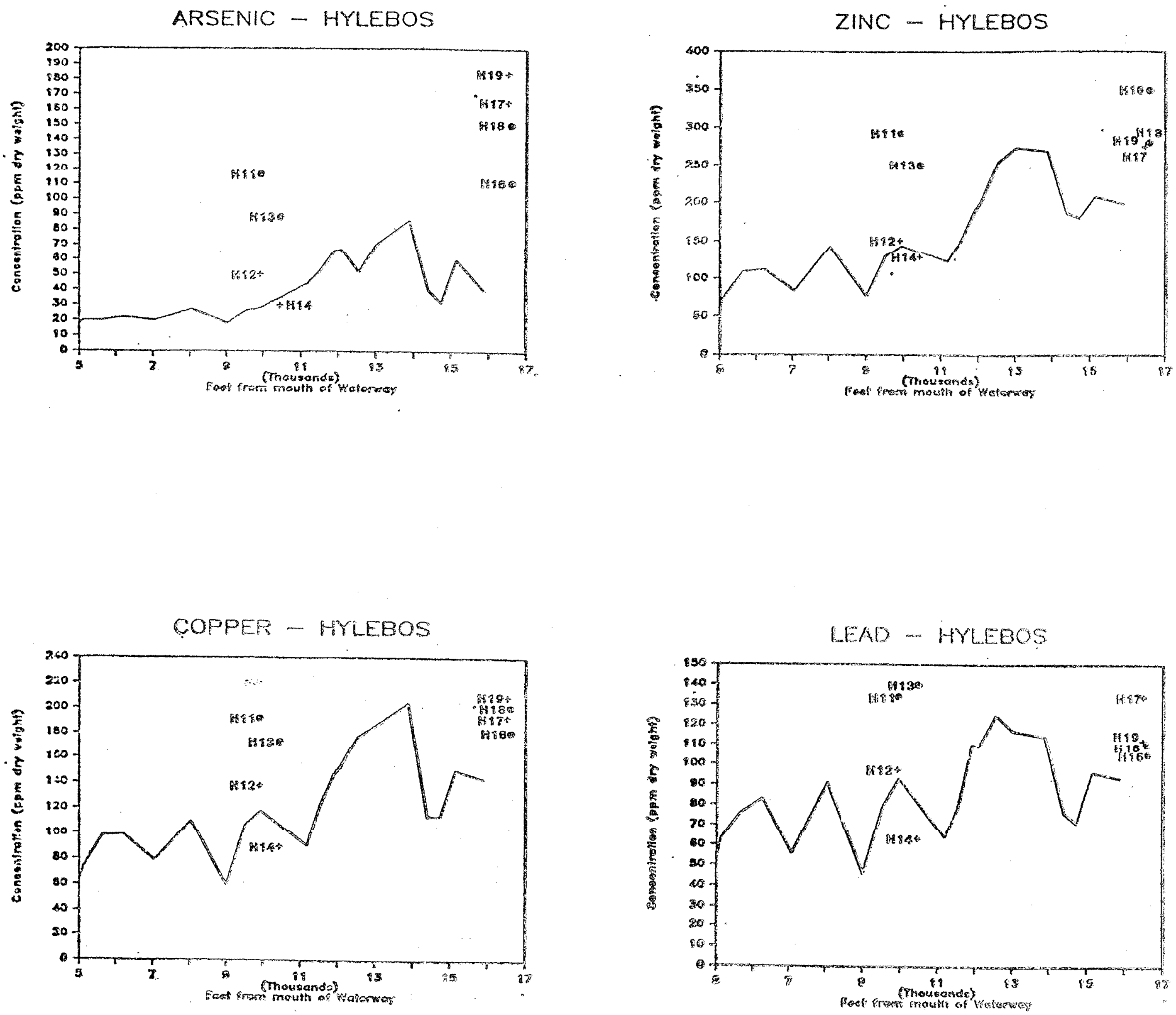
● Nearshore
+ Offshore = WDOE station

Solid line = Tetra Tech mid-channel transect

A = WDOE data suspect due to analytical technique.

B = Tetra Tech data suspect due to analytical technique.

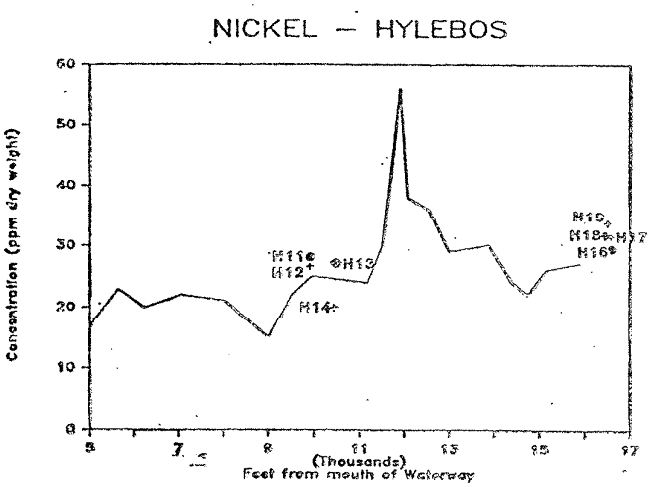
Figure 7. (continued)

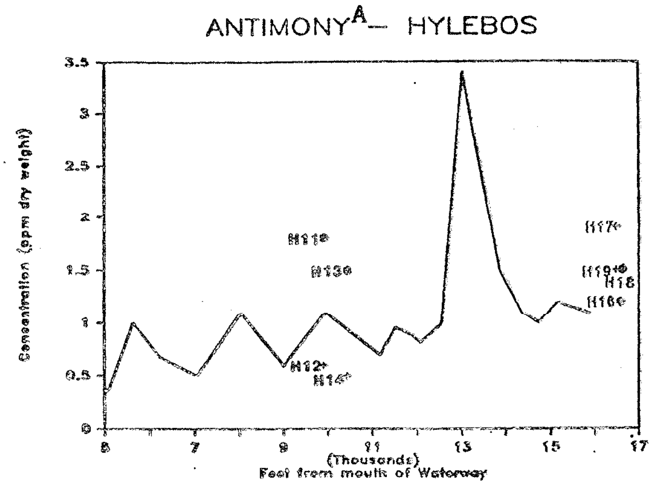


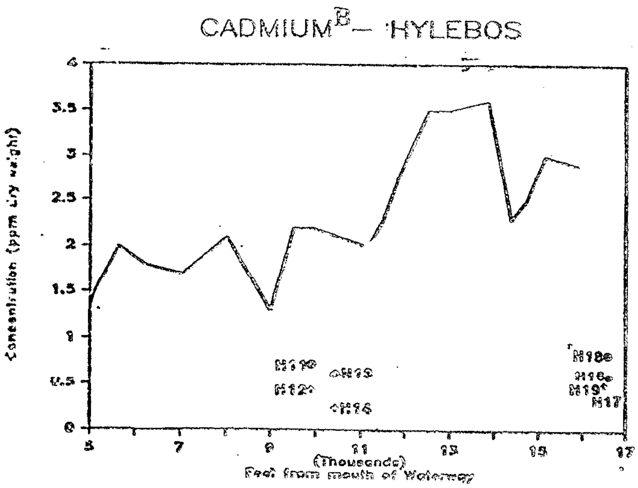
● Nearshore
\+ Offshore = WDOE station

Solid line = Tetra Tech mid-channel transect

Figure 8. Comparison of metals concentrations in Hylebos Waterway subtidal sediments of Murry Pacific yard #1 and Wasser/Winters collected June 14, 1984, by WDOE to a mid-channel transect sampled March 11-18, 1984, by Tetra Tech, Inc.







● Nearshore
+ Offshore = WDOE station

Solid line = Tetra Tech mid-channel transect

A = WDOE data suspect due to analytical technique.

B = Tetra Tech data suspect due to analytical technique.

Figure 8. (continued)

Sample collection methods for the Tetra Tech samples were the same as described for the present WDOE survey. However, metals analyses were done under the EPA Contract Laboratory Program (CLP) by Rocky Mountain Analytical Laboratories rather than by EPA/WDOE Manchester. Digestion procedures were performed using the CLP $HNO_3:H_2O_2$ standard procedure. Samples were analyzed for zinc, copper, lead, nickel, and cadmium using inductively coupled plasma spectrometry (ICP). Graphite furnace atomic absorption was used for arsenic analysis.

In Blair Waterway sediments (Figure 7), there is a longitudinal gradient for arsenic, zinc, copper, and lead, with peak concentrations occurring at approximately mid-waterway in the vicinity of Murry Pacific yard #2 and South Lincoln Avenue ditch. A similar pattern is not seen for nickel, antimony, and cadmium. Arsenic, zinc, copper, and lead are in most cases the highest in nearshore samples adjacent to Murry Pacific yard #2. Arsenic, zinc, and copper concentrations in these nearshore sediments are approximately twice as high as the median concentrations for Blair Waterway based on the Tetra Tech mid-channel transect. Station B-6 had a much higher sand content and lower organic carbon and nitrogen concentration compared to other samples, which probably explains the relatively low metals concentrations in this nearshore sample. Nickel concentrations were similar in both data sets. Antimony in offshore samples and cadmium in all WDOE samples were substantially lower than Tetra Tech's mid-channel transect, perhaps reflecting analytical differences between the EPA/WDOE laboratory and EPA contract laboratory which performed the analyses. Mid-channel sediment cadmium data reported by the EPA contract laboratory were noted as suspect during QA review by Tetra Tech because the analyses were performed at or near the detection limit of the ICP instrument, and likely overestimated the actual concentrations (Bailey, 1984). In addition, the HNO_3 and H_2O_2 digestion procedure used for analysis by both laboratories is not a total sediment digestion procedure for all metals. Variable results can be obtained when a partial digestion procedure is used depending on the exact time period and temperature used for the digestion (EPA/COE, 1981). Unless both laboratories employed the same digestion time and temperature, variable extraction of the acid soluble antimony and cadmium could result.

The Wapato Creek sediment data are not included in Figure 7, but show a threefold increase in arsenic concentration between samples collected above and below Portac's discharges to the creek.

A different longitudinal gradient was seen in Hylebos Waterway (Figure 8). Metals concentrations were generally higher at the head of the waterway and gradually decreased toward the mouth. Concentrations were more variable than in Blair Waterway. Arsenic, zinc, copper, and lead concentrations were higher in nearshore sediments at Murry Pacific yard #1 than in offshore sediments. Nearshore and offshore sediments at Wasser/Winters were not substantially different, perhaps because the major discharge from Wasser/Winters reaches the waterway via Hylebos Creek. The highest arsenic concentrations found in the present survey were in Hylebos Waterway sediments adjacent to Wasser/Winters and Hylebos Creek. Nickel and antimony concentrations were similar in WDOE and Tetra Tech samples; Tetra Tech's results for cadmium were lower than WDOE's. These antimony and cadmium data, however, should be used cautiously because of the previously mentioned analytical differences between the two laboratories.

Table 19 compares data on arsenic, zinc, copper, and lead in sediments from the present survey to Tetra Tech data on Blair, Hylebos, City, Sitcum, St. Paul, Middle, and Milwaukee Waterways and Carr Inlet, the background station selected for the Commencement Bay Nearshore/Tideflats Investigation. Based on median concentrations, sediments near log sort yards in Blair Waterway are 12 to 14 times higher than background (Carr Inlet) levels for arsenic and copper; zinc and lead are five to six times greater than background. Arsenic concentrations in these sediments are also twice as high as the median concentration for Sitcum Waterway and six times higher than those in City Waterway.

Table 19. Comparison of metals concentrations in sediment adjacent to log sort yards in Blair and Hylebos Waterways to other parts of Commencement Bay and Carr Inlet (mg/Kg dry weight).

Site/Parameter	Sample Size	Arsenic	Zinc	Copper	Lead
Blair Waterway[1]	9	46(26-57)	114(59-140)	93(38-127)	55(20-86)
" " [2]	11	19(7-36)	68(35-85)	54(28-64)	53(27-64)
Hylebos Waterway[1]	8	114(30-184)	278(129-349)	187(90-206)	111(63-140)
" " [2]	24	30(5.8-86)	137(21-273)	111(14-204)	79(8.3-134)
City Waterway[2]	11	8(1.1-33)	234(44-325)	166(40-203)	291(49-725)
Sitcum Waterway[2]	5	28(10-93)	254(109-491)	158(74-292)	310(128-661)
St. Paul Waterway[2]	5	7.0(5.5-12)	60(29-106)	56(29-82)	24(11-52)
Middle Waterway[2]	3	39(15-67)	178(158-208)	311(176-554)	190(188-303)
Milwaukee Waterway[2]	5	10(9.5-19)	105(63-135)	60(46-77)	62(48-78)
Carr Inlet[2]	6	3.8(2.4-3.8)	18(15-24.1)	6.3(4.9-8.0)	11(4.4-13)

median(range)

[1]WDOE present survey (samples collected June 14, 1984).

[2]Tetra Tech main sediment survey (samples collected March 11-18, 1984).

In Hylebos Waterway, nearshore sediments are 10 to 30 times higher than background (Carr Inlet) levels for arsenic, zinc, copper, and lead. Arsenic and zinc concentrations in these sediments are also the highest measured in any Commencement Bay waterway.

A comparison of metals concentrations in ASARCO slag to WDOE data on log sort yard runoff, nearshore surface water, and sediment collected during the present study is shown in Table 20. Two analyses of ASARCO slag were available, the first done in 1971 by ASARCO utilizing atomic absorption spectrometry (except for arsenic which was analyzed by the silverdiethyldithiocarbonate method), and the second performed by E.A. Crecelius of Battelle Pacific Northwest Laboratories in 1984 using X-ray fluoresence spectroscopy. Both analyses showed high concentrations of arsenic, zinc, copper, lead, and antimony in ASARCO slag. Similar metals concentrations were seen in both analyses, with the exception of zinc, which was approximately three times higher in ASARCO's analysis than in Battelle's (18,000 ppm and 6,100 ppm, respectively). However, it is not unusual for the metals content of slag to vary depending on the source and type of ore being smelted (Crecelius, 1985).

There appear to be approximately constant arsenic:zinc:copper ratios in log sort yard runoff samples (Table 20), with the exception of zinc, which is relatively high in runoff from Murry Pacific yard #1. The constant ratio of these three metals suggests a common source of metals at each yard. While not as pronounced, a similar pattern was also seen in nearshore surface waters and sediment. The relative abundance of zinc and copper appears to increase moving from runoff to surface water to sediment. Variable recoveries in the analysis of different medias, in addition to complex physical/chemical reactions taking place when runoff mixes with saltwater, make it difficult to draw strong conclusions from the relative abundance of these metals.

Arsenic:zinc:copper ratios provide some evidence for a match between ASARCO slag and runoff. These ratios also suggest that arsenic may be more readily leached from slag than zinc and copper; however, several factors including variable slag characteristics, environmental variables affecting leaching rates, and relationships between total and dissolved metals in runoff complicate these comparisons. Therefore, without analyzing slag by the same analytical techniques as runoff from each of the log sort yards sampled, it is not surprising a perfect match does not exist. A strong possibility exists, however, that ASARCO slag is the major source of the elevated metals concentrations seen in log sort yard runoff, nearshore surface water, and sediment.

Summary

The major findings of this study are as follows:

1. High concentrations of arsenic (122 to 12,000 ug/L), zinc (102 to 5,300 ug/L), copper (73 to 4,000 ug/L), and lead (9 to 2,400 ug/L) were present in runoff from ten of the twelve log sort yards on the Tacoma Tideflats. Runoff from the two remaining yards, Weyerhaeuser and St. Regis, had concentrations approximately one to two orders of magnitude lower.

2. Suspended solids concentrations were elevated in sort yard runoff, with concentrations as high as 7,800 mg/L.

3. The range of metals loads measured in runoff from the four yards investigated in detail, Murry Pacific yards #1 and #2, Portac, and Wasser/Winters, were as follows: arsenic, 0.25 to 38 lbs/day; zinc, 0.21 to 15 lbs/day; copper, 0.03 to 4.7 lbs/day; and lead, 0.051 to 2.7 lbs/day. Arsenic loads from Murry Pacific yard #2, the largest yard monitored, were, in most cases, much higher than those from other yards.

4. Based on their estimated average annual daily metals loads, Murry Pacific yard #2, Cascade Timbers yard #2, Portac, and Wasser/Winters are consistently the highest for arsenic, copper, and lead. With the exception of Wasser/Winters, these yards also have the highest load for zinc.

Table 20. Comparison of metals concentrations in ASARCO slag to WDOE data collected May 3, 1984, on log sort yard runoff, nearshore surface water, and sediment in blair and Hylebos Waterways and Wapato Creek (total metal; ppm slag, mg/L water, mg/Kg dry weight sediment).

	ASARCO Slag		Blair Waterway			Wapato Creek			Hylebos Waterway					
			Murry Pacific Yard #2			Portac			Wasser/Winters			Murry Pacific Yard #1		
Metal	Total[1]	Total[2]	Runoff[3]	Nearshore Surface Water[4]	Near-shore Sedi-ment[4]	Runoff[3]	Down-stream Water[4]	Down-stream Sedi-ment	Ruroff[3]	Near-shore Surface Water[4]	Near-shore Sedi-ment[4]	Runoff[3]	Near-shore Surface Water[4]	Near-shore Sedi-ment[4]
Arsenic	9,000	7,300	4.4	0.065	52	9.5	0.070	45	12.0	0.047	130	1.3	0.062	100
Zinc	18,000	6,100	0.69	0.033	130	2.1	0.065	78	1.7	0.049	320	1.2	0.074	270
Copper	5,000	4,100	0.45	0.024	110	1.0	0.034	23	1.2	0.039	190	0.15	0.029	180
Lead	5,000	3,600	0.30	0.010	69	0.38	0.011	10	0.83	0.017	110	0.27	0.013	140
Nickel	trace	130	0.043	0.001u	13	0.12	0.001u	6.2	0.12	0.001u	31	0.037	0.001u	28
Antimony	6,000	6,400	0.068	0.0013	1.4	0.12	0.001u	0.1u	0.028	0.003	1.4	0.072	0.005	1.7
Cadmium	--	5	0.00098	0.0004	0.35	0.002	0.0002	0.16	0.0013	0.00013	0.72	0.0009	0.0003	0.68
As:Zn:Cu	1:2:0.6	1:0.8:0.6	1:0.2:0.1	1:0.5:0.4	1:3:2	1:0.2:0.1	1:0.9:0.5	1:2:0.5	1:0.1:0.1	1:1:0.8	1:2:1	1:0.9:0.1	1:1:0.5	1:3:2

[1]Source: State of Washington Discharge Permit Application, 1971; ASARCO.
[2]Source: E.A. Crecelius, 1985. Battelle Pacific Northwest Laboratory, personal communication.
[3]Flow-weighted average concentration.
[4]Average

-- = No data.
u = Not detected at detection limit shown.

5. The annual metals loads (lbs/year) to Commencement Bay waterways from all twelve log sort yards combined was estimated to be: arsenic - 2,500; zinc - 1,100; copper - 510; lead - 310; nickel - 66; antimony - 50; and cadmium - 2.0.

6. Average arsenic loads from Murry Pacific Yard #2 and Portac - 20 lbs/day and 6.8 lbs/day, respectively, are the highest WDOE has measured in discharges to Blair Waterway. Similarly, discharges from Wasser/Winters probably constituite the largest arsenic load to Hylebos Waterway during storm events. The order of magnitude difference between average measured arsenic loads and average annual daily arsenic loads indicates that arsenic loadings from the log sort yards are the greatest during storm events.

7. In Blair Waterway, substantial concentration gradients were observed in the surface waters for arsenic, zinc, and copper. The highest concentrations occur at approximately mid-waterway near Murry Pacific yard #2 and South Lincoln Avenue ditch. Arsenic concentrations in nearshore samples adjacent to Murry Pacific yard #2 and South Lincoln Avenue ditch were substantially higher than offshore samples. A secondary concentration peak was also present at the head of the waterway near the mouth of Wapato Creek. Arsenic levels in Wapato Creek increased by a factor of 35 below Portac discharges.

   In Hylebos Waterway, longitudinal concentration gradients were not as marked as in Blair; however, nearshore samples at Murry Pacific yard #1 and Wasser/Winters had higher arsenic and zinc concentrations than offshore samples. Copper was also elevated at Wasser/Winters, but not at Murry Pacific yard #1.

8. EPA acute criteria for the protection of saltwater aquatic life were exceeded for zinc and copper, in both Blair and Hylebos surface waters adjacent to discharges at Murry Pacific yards #1 and #2 and Wasser/Winters. EPA acute criteria for arsenic were not exceeded in either waterway. Zinc concentrations in runoff from the previously mentioned yards would require a 2- to 29-fold dilution with uncontaminated water, while copper would need anywhere from a 4- to 120-fold dilution to meet EPA acute criteria. Locally toxic conditions for aquatic organisms could exist in nearshore receiving waters during storm events until sort yard runoff is completely mixed, especially since a high proportion of the arsenic, zinc, and copper present in runoff is in the dissolved form.

9. Sediments from Blair Waterway adjacent to Murry Pacific yard #2 contain arsenic, zinc, and copper concentrations two times higher than the rest of Blair Waterway. These sediments are also twelve to fourteen times higher than background (Carr Inlet) levels for arsenic and copper, and five to six times higher for zinc and lead.

10. Hylebos Waterway sediments near Murry Pacific yard #1 and Wasser/Winters have concentrations of arsenic, zinc, copper, and lead which are two to four times higher than sediments in the rest of Hylebos Waterway. These sediments are also twice as high in arsenic, zinc, copper, and lead compared to sediments off sort yards in Blair Waterway, and ten to thirty times higher than background (Carr Inlet) levels for these metals.

11. The highest arsenic and zinc concentrations reported for sediment from any Commencement Bay waterway are adjacent to Wasser/Winters sort yard and Hylebos Creek at the head of Hylebos Waterway.

Conclusions

The common occurrence of high concentrations of arsenic, zinc, copper, and lead in ASARCO slag and in log sort yard runoff, the relatively constant metals ratio in runoff from different yards, and the fact that sort yard runoff is unique among discharges to Commencement Bay waterways in its high metals content, indicate the use of slag as ballast is the source of the problem. The impacts of sort yard runoff on metals distributions in Blair and Hylebos Waterways are evidenced by strong concentration gradients in both surface waters and sediment which point to sort yards as sources. Runoff from slag-ballasted yards has the potential to raise arsenic, zinc, and copper concentrations in adjacent receiving waters, and perhaps sediment, to levels toxic to marine life.

The potential impacts on groundwater associated with the usage of slag at the log sort yards is still a major unresolved issue. Groundwater flux may be a major mechanism by which metals are transported to the waterways. Potential impacts of metals on groundwater and subsequent transport to the waterways should be addressed and considered as remedial actions are proposed and evaluated.

Recommendations

1. Immediately discontinue the use of slag for ballast.

2. Investigate the possibility of metals contamination of groundwater in the vicinity of the log sort yards.

3. Remedial actions should be evaluated and implemented to substantially reduce or eliminate metals and suspended solids flux from the log sort yards to ground- or surface waters.

4. Priority areas to address with respect to remedial actions should be Hylebos and Wapato Creeks in the vicinity of the log sort yards. Since dilution is relatively small in the creeks compared to that available in the waterway, adverse impacts to aquatic organisms especially juvenile salmonids could potentially be reduced in these areas.

DN:AJ:cp

Attachments

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Figure A. Slag used for ballast. Portac sort yard, Tacoma tideflats, October 12, 1983.

Appendix I. Results of conventional parameters and metals analysis on log sort yard runoff collected by WDOE November 1983 - June 1984 (ug/L total metal).

Sort Yard	Discharge Number	Date	Flow (MGD)	pH (S.U.)	Spec. Cond. (umhos/cm)	Total Susp. Solids (mg/L)	Total non-vol. Susp. Solids (mg/L)	Arsenic	Zinc	Copper	Lead	Nickel	Antimony	Cadmium
Murry Pacific Yard #2	1	11/04/83	0.043	4.8	161	550	--	4,900	970	318	389	76	66	1.4
" " " "	2	"	0.042	5.0	167	2,900	--	7,700	2,920	945	747	138	22	3.0
" " " "	3	"	0.00093	5.0	140	2,600	--	10,100	4,060	2,630	927	159	325	4.6
" " " "	4	"	0.00076	4.9	167	270	--	12,400	2,135	745	472	110	183	2.3
" " " "	5	"	0.05	5.3	113	750	--	6,400	947	327	471	75	36	1.4
" " " "	6	"	0.08	5.3	136	320	--	10,100	2,190	645	580	81	49	2.3
" " " "	7	"	0.02	5.3	168	1,500	--	12,000	1,810	835	603	68	23	1.9
" " " "	8	"	0.06	5.7	242	13,000	--	23,000	13,680	4,980	1,023	403	90	11.5
" " " "	S1	"	0.053	5.4	159	390	--	10,100	1,250	409	564	140	44	1.7
" " " "	1	12/29/83	0.14	5.0	78	62	24	1,040	256	81*	52*	10	--	0.2
" " " "	2	"	0.02	4.7	102	210	110	1,740	309	106	83	18	--	0.2
" " " "	2†	"	--	--	--	--	--	1,700	181	40*	27*	9	--	0.2u
" " " "	3	"	0.01	5.2	69	83	40	1,580	423	140	78	11	--	0.2
" " " "	4	"	0.14	5.1	66	80	36	2,290	323	110	80	10	--	0.2
" " " "	Port Way	"	0.92	5.5	57	230	160	1,580	525	254	201	21	--	0.5
" " " "	" " (dup)	"	--	--	--	--	--	1,600	534	267	207	16	--	0.5
" " " "	5	"	0.17	5.6	65	410	260	1,650	621	416	237	51	--	0.7
" " " "	6	"	0.30	5.4	65	80	44	2,050	372	183	123	11	--	0.3
" " " "	7	"	0.15	5.3	93	780	710	3,600	541	228	135	30	--	0.5
" " " "	8	"	0.14	5.2	80	150	100	3,600	568	238	161	21	--	0.4
" " " "	8†	"	--	--	--	--	--	3,300	339	69*	38*	9	--	0.3
" " " "	S1	"	0.16	5.2	692	66	53	4,200	225	89	56*	11	--	0.2
" " " "	1	03/12/84	0.0085	5.8	79	160	94	3,500	437	150*	180	19	18	0.6
" " " "	1a	"	0.0046	5.1	155	740	440	4,100	1,126	310	255	92	18	0.8
" " " "	2	"	0.007	5.6	94	1,000	670	6,800	997	470	330	92	15	1.3
" " " "	2†	"	--	--	--	--	--	5,500	266	60*	44	14	59	0.2u
" " " "	4	"	0.028	5.6	100	13,000	810	13,000	2,585	1,570	1,280	128	66	3.2
" " " "	Port Way	"	0.17	6.3	178	580	400	5,000	1,229	772	595	78	30	1.9
" " " "	5 (rep)	"	0.019	5.8	96	300	200	5,000	848	520	394	37	29	1.0
" " " "	5 (rep)	"	--	--	--	--	--	5,500	851	498	330	44	34	1.6
" " " "	5 (rep)	"	--	--	--	--	--	5,800	860	497	390	47	33	1.2
" " " "	6	"	0.037	5.8	114	250	170	10,300	1,207	661	480	50	51	1.4
" " " "	7	"	0.0012	5.7	125	700	490	9,200	2,875	1,205	980	87	53	2.9
" " " "	8	"	0.017	5.9	128	2,300	1,700	15,000	6,050	3,330	3,150	190	101	8.1
" " " "	8†	"	--	--	--	--	--	8,700	593	133	180	36	129	0.4
" " " "	S1	"	0.018	6.0	99	390	310	8,800	669	392	402	35	59	0.8
" " " "	1	04/10/84	0.0076	5.7	96	490	390	6,750	2,840	1,610	1,610	240	62	2.5
" " " "	1a	"	0.0065	5.1	96	120	84	3,940	832	353	322	85	43	0.9
" " " "	2	"	0.00077	6.2	95	84	52	9,300	708	307	227	50	77	0.5
" " " "	4	"	0.0084	6.2	92	260	140	11,600	1,440	674	583	97	89	2.0
" " " "	4†	"	--	--	--	--	--	10,000	419	121*	79*	3	87	0.5
" " " "	Port Way	"	0.056	6.6	207	230	140	5,420	1,240	732	570	52	32	1.4
" " " "	5	"	0.0065	6.0	110	530	370	9,100	2,170	1,450	1,100	195	23	2.9
" " " "	6	"	0.011	5.6	153	980	680	19,200	4,720	3,270	3,160	340	136	6.4
" " " "	8	"	0.0038	5.9	147	2,200	1,400	14,800	7,450	4,680	4,510	373	173	9.1
" " " "	8†	"	--	--	--	--	--	2,860	202	30*	41*	6	48	0.2
" " " "	S1	"	0.0056	6.2	115	28	16	3,440	277	98	58*	14	11	0.6
" " " "	1	05/03/84	0.011	5.1	125	340	220	4,440	610	865	276	46	5	0.1
" " " "	1a	"	0.00088	5.5	133	110	68	3,660	598	1u	252	39	4	0.1u
" " " "	2	"	0.00054	6.1	105	36	76	4,920	557	185	132	21	129	0.1u
" " " "	4	"	0.0028	6.1	98	21	15	7,660	646	193	67	9	29	0.3
" " " "	4†	"	--	--	--	--	--	6,860	506	155	30	20	40	0.3
" " " "	Port Way	"	0.065	6.6	378	560	460	3,160	647	421	314	46	5	1.3
" " " "	5	"	0.0077	5.9	132	110	58	6,940	748	444	296	24	137	0.6
" " " "	5 (dup)	"	--	--	--	--	--	6,820	758	405	312	42	132	0.8
" " " "	6 (rep)	"	0.013	5.8	122	70	36	7,380	574	211	68	41	23	0.7
" " " "	6 (rep)	"	--	--	--	--	--	8,640	843	426	288	30	71	0.5
" " " "	6 (rep)	"	--	--	--	--	--	8,420	850	437	287	27	19	0.6
" " " "	8	"	0.0029	5.9	145	320	190	9,220	2,280	1,200	1,190	99	33	2.3
" " " "	8†	"	--	--	--	--	--	6,140	544	211	89	23	129	0.9
" " " "	S1	"	0.0011	6.1	169	52	22	12,860	463	389	295	37	38	0.5
" " " "	S2	"	0.0016	5.8	129	60	30	4,820	836	378	188	35	172	0.7

-- = Not analyzed
† = Dissolved metals.
* = Data deleted due to field blank contamination.
u = Not detected at detection limit shown.

Appendix I. Results of conventional parameters and metals analysis on log sort yard runoff collected by WDOE November 1983 - June 1984 (ug/L total metal).

Sort Yard	Discharge Number	Date	Flow (MGD)	pH (S.U.)	Spec. Cond. (umhos/cm)	Total Susp. Solids (mg/L)	Total non-vol. Susp. Solids (mg/L)	Arsenic	Zinc	Copper	Lead	Nickel	Antimony	Cadmium
Portac	1	11/04/83	0.006	5.3	1,720	100	--	2,300	6,880	1,290	228	263	315	10.7
"	2	"	0.18	5.7	1,410	120	--	4,500	5,110	1,660	312	301	166	11
"	3	"	0.17	5.9	318	86	--	1,300	4,720	1,135	263	241	111	9.5
"	5	"	0.008	5.7	204	210	--	600	2,545	915	195	153	60	6.2
"	1	12/29/83	0.29	5.6	549	28	13	920	851	276	50*	25	--	0.7
"	2 (rep)	"	0.13	5.9	104	23	15	3,900	3,130	867	138	173	--	2.0
"	2†	"	--	--	--	--	--	3,700	2,660	751	43*	149	--	2.0
"	2 (rep)	"	--	--	--	--	--	3,600	2,900	833	102	169	--	2.0
	2 (rep)	"	--	--	--	--	--	3,700	3,080	859	117	192	--	2.1
"	3	"	1.4	5.9	49	28	20	260	554	266	38*	17	--	1.0
"	1	03/12/84	0.045	5.9	732	240	68	8,900	3,625	2,170	950	165	490	4.8
"	2	"	0.015	6.1	931	24	2	19,900	4,440	3,190	645	242	1,030	3.9
"	2†	"	--	--	--	--	--	18,900	3,500	1,750	213	171	1,235	2.2
"	3	"	0.045	6.3	138	72	47	1,730	1,174	630	228	69	93	2.3
"	1	04/10/84	0.027	6.2	933	68	30	8,700	1,640	864	361	152	162	3.2
"	1†	"	--	--	--	--	--	2,760	924	74*	90*	50	123	1.8
"	2	"	0.002	6.4	780	18	2	8,700	3,620	2,480	383	214	536	3.9
	2 (dup)	"	--	--	--	--	--	8,500	3,410	2,530	370	212	459	4.2
"	3	"	0.066	6.3	346	64	44	4,460	1,610	612	235	57	130	2.8
"	1	05/03/84	0.029	6.5	1,030	96	42	13,550	2,320	829	329	165	73	2.1
"	2	"	0.00064	6.3	1,390	120	60	8,760	4,370	3,040	434	237	445	2.9
"	2†	"	--	--	--	--	--	6,640	3,550	1,480	127	179	430	1.7
"	3	"	0.028	6.4	357	80	42	5,400	1,880	1,160	430	79	158	2.0
Wasser/Winters	1	11/04/83	0.03	5.4	261	2,300	--	9,700	4,230	2,040	795	259	223	6.0
" "	2	"	0.04	5.6	211	370	--	5,200	1,143	249	348	116	52	1.5
" "	1	12/29/83	0.10	5.1	190	410	250	2,360	908	336	302	34	--	1.6
" "	1†	"	--	--	--	--	--	1,790	465	66*	33*	6	--	0.7
" "	2	"	0.15	6.0	39	10	3	450	104	25*	24*	1u	--	0.3
" "	3	"	0.009	5.4	434	92	48	1,420	375	169	110	16	--	0.4
" "	4	"	0.03	5.1	407	490	320	2,220	688	294	205	34	--	0.4
" "	5	"	0.031	6.0	3,250	480	330	2,300	823	276	184	55	--	0.9
" "	1	03/12/84	0.029	5.7	228	4,900	3,200	21,600	11,930	10,160	5,900	419	266	16.1
" "	1†	"	--	--	--	--	--	11,400	1,087	109*	61	65	99	0.6
" "	2	"	0.034	6.4	70	120	88	198	294	102*	93	28	6	1.6
"	3	"	0.0017	5.7	223	8,600	6,400	7,000	5,550	4,470	3,000	512	35	6.7
" "	4	"	0.0032	5.6	399	240	120	8,800	612	234	146	89	39	0.5
" "	5	"	0.084	6.4	1,000	740	450	6,800	1,328	1,350	740	86	92	2.9
" "	1 (rep)	04/10/84	0.08	6.9	52	340	230	1,680	876	662	410	42	31	1.2
" "	1 (rep)	"	--	--	--	--	--	1,680	782	620	412	37	82	1.3
	1 (rep)	"	--	--	--	--	--	1,310	1,033	616	381	39	27	1.4
" "	1†	"	--	--	--	--	--	710	51*	25*	53*	1u	6*	0.2
" "	2	"	0.002	6.7	74	30	26	250	222	37*	97*	1u	5*	1.1
" "	2a	"	0.01	6.2	235	420	310	14,200	945	647	479	120	47	1.9
" "	3	"	0.00094	6.6	186	44	32	10,000	403	184	195	1u	30	0.4
" "	4	"	0.00036	5.5	435	420	320	5,560	652	307	237	32	11*	0.9
" "	5	"	0.0012	5.9	2,330	110	42	8,000	460	144	150	11	86	0.7
" "	1	05/03/84	0.0026	5.7	400	6,300	2,400	24,800	6,140	4,090	2,780	338	83	4.6
" "	1†	"	--	--	--	--	--	12,450	971	175	62	52	22	0.5
" "	2	"	0.0091	6.3	292	800	600	11,440	867	674	535	89	18	0.7
" "	2a	"	0.0018	6.8	147	41	32	710	205	20	1u	6	4	0.1
" "	3	"	0.0076	5.5	423	130	80	3,820	412	308	89	28	8	0.1
" "	5	"	0.001	6.1	1,940	120	54	10,280	1,285	489	308	49	24	0.5

-- = Not analyzed.
† = Dissolved metals.
* = Data deleted due to field blank contamination.
u = Not detected at detection limit shown.

Appendix I. Results of conventional parameters and metals analysis on log sort yard runoff collected by WDOE November 1983 - June 1984 (ug/L total metal).

Sort Yard	Discharge Number	Date	Flow (MGD)	pH (S.U.)	Spec. Cond. (umhos/cm)	Total Susp. Solids (mg/L)	Total non-vol. Susp. Solids (mg/L)	Arsenic	Zinc	Copper	Lead	Nickel	Antimony	Cadmium
Murry Pacific Yard #1	1	11/04/83	0.08	6.7	11,400	9	--	945	961	80*	24*	28*	64	0.9
" " " "	3	"	0.045	5.6	257	14	--	1,480	4,360	286	80*	127	73	6.2
" " " "	1	12/29/83	0.39	6.5	16,500	17	6	345	385	86*	38	5	--	0.3
" " " "	1†	"	--	--	--	--	--	210	363	42*	18	5	--	0.4
" " " "	2	"	0.23	6.1	47	34	20	565	760	130	92	5	--	0.7
" " " "	3	"	0.11	5.7	45	90	45	950	959	285	254	13	--	1.0
" " " "	1	03/12/84	0.035	7.2	5,770	20	11	1,270	440	140*	101	24	75	0.7
" " " "	1†	"	--	--	--	--	--	202	226	55*	26*	8	22	0.4
" " " "	1 (dup)	"	--	--	--	--	--	1,190	442	131*	105	14	66	0.6
" " " "	2	"	0.0054	6.1	140	270	130	9,800	4,130	1,320	1,310	81	366	5.5
" " " "	3	"	0.017	6.0	139	100	50	3,300	2,945	710	555	47	145	3.4
" " " "	1	04/10/84	0.021	7.0	4,540	13	6	1,780	368	180	111*	191	74	0.4
" " " "	1†	"	--	--	--	--	--	710	282	75*	84	1u	36	0.7
" " " "	2	"	0.0041	6.6	168	180	83	5,880	3,890	1,430	1,620	170	274	5.6
" " " "	3	"	0.017	6.4	131	38	21	4,800	1,950	459	433	80	107	3.4
" " " "	1	05/03/84	0.012	7.1	7,810	24	10	1,090	190	90	38	15	33	0.1
" " " "	1†	"	--	--	--	--	--	540	136	55	1	5	40	0.1u
" " " "	3	"	0.011	6.5	147	63	38	1,500	2,280	224	518	62	115	1.8
Cascade Timber Yard #1	1	12/12/83	0.003	7.3	247	270	--	7,280	3,000	695	710	188	71	4.2
" " " "	1	06/29/84	--	5.7	265	110	4	1,970	1,685	148	36	56	105	3.0
" " " #2	1	12/12/83	0.005	7.3	841	27	--	122	59*	33*	23*	22	1u	0.2u
" " " "	1	06/29/84	0.065	5.9	437	7,800	5,600	4,790	5,340	4,000	4,940	325	155	15.5
Dunlap Towing	1	11/04/83	--	--	--	--	--	3,800	1,425	183	267	40*	91	3.4
	1	06/29/84	--	7.5	1,380	72	28	2,680	315	342	171	27	259	0.8
Louisiana Pacific	1	12/12/83	0.023	6.9	951	1,000	--	2,160	656	550	385	215	118	1.1
" "	2	"	0.026	7.1	832	52	--	2,200	505	400	335	46	41	1.6
" "	3	"	0.011est	6.8	492	110	--	1,135	172	120	88	42	23	0.3
"	1	06/29/84	0.0077	7.2	783	260	200	401	184	90	69	19	1u	0.6
" "	2	"	0.00038	7.2	1,270	240	170	1,790	592	83	34	16	6	0.6
" "	3	"	0.012	6.8	307	40	7	560	113	75	33	7	6	0.4
" "	4	"	0.046	7.3	2,270	310	260	995	180	70	4	13	6	0.1u
Weyerhaeuser	1	01/05/83	0.004	4.6	480	1,200	--	32	313	56*	27*	64	2	0.4
"	2	"	0.02	5.8	345	650	--	32	212	48*	61*	44	4	0.4
"	1	06/29/84	0.022	4.9	216	1,700	480	25	519	143	43	73	1	1.8
"	2	"	0.064	5.3	184	1,400	430	51	692	114	32	67	1u	1.9
McFarland Cascade	1	11/04/83	0.15	5.6	511	150	--	250	445	86*	54*	73	12*	1.4
"	1	06/29/84	0.038	6.3	144	160	110	1,115	225	171	33	13	14	0.2
Cascade Timber Yard #3	1	12/12/83	0.11	6.9	841	200	--	156	102	78*	52*	18	1u	0.2u
" " " "		06/29/84	--	6.7	248	210	130	1,750	293	138	69	17	8	0.5
St. Regis Sort Yard	1	06/29/84	0.026	6.6	521	260	130	25	97	65	17	7	2	0.4

-- = Not analyzed.
† = Dissolved metals.
* = Data deleted due to field blank contamination.
u = Not detected at detection limit shown.
est = Estimated

Appendix II. Station numbers† entered in the Commencement Bay data base for the WDOE log sort yards survey, November 4, 1983 - June 29, 1984.

Sort Yard	WDOE Station Number (this report)	Station Number in the Commencement Bay Data Base
Murry Pacific Yard #2	1	MP201
" " " "	1a	MP209
" " " "	2	MP202
" " " "	3	MP203
" " " "	4	MP204
" " " "	PW	MP210
" " " "	5	MP205
" " " "	6	MP206
" " " "	7	MP207
" " " "	8	MP208
" " " "	S1	MPS-1
" " " "	S2	MPS-2
Portac	1	PTO 1
"	2	PTO 2
"	3	PTO 3
"	5	PTO 5
Wasser/Winters	1	WW01
" "	2	WW02
" "	2a	WW06
" "	3	WW03
" "	4	WW04
" "	5	WW05
Murry Pacific Yard #1	1	MP101
" " " "	2	MP102
" " " "	3	MP103
Cascade Timber Yard #1	1	CTO 1
Cascade Timber Yard #2	1	CTO 2
Dunlap Towing	1	DTO 1
Louisiana Pacific	1	LPO 1
" "	2	LPO 2
" "	3	LPO 3
" "	4	LPO 4
Weyerhaeuser	1	WYO 1
"	2	WYO 2
McFarland Cascade	1	MCO 1
Cascade Timber Yard #3	1	CTO 3
St. Regis	1	SRO 2

†Station locations shown in Figures 2a - 2e.

Appendix III. Results of metals analysis of field blanks for Tacoma tideflats log sort yard samples collected by WDOE November 1983 - June 1984 (ug/L total metal).

Date of Survey	Sample Number	Arsenic	Zinc	Copper	Lead	Nickel	Antimony	Cadmium
11/04/83	136132	1u	1.0	24	29	8.0	3.0	0.1u
12/12/83	136740	1u	13	18	12	1u	1u	0.2u
12/29/83	136959	1u	13	17	13	1u	--	0.2u
03/12/84	141014	3.0	5.0	42	8.0	1u	1u	0.2u
"	141013†	15	9.0	24	8.0	1u	2.0	0.2u
04/10/84	141485	24	12	10	24	1u	3	0.1u
"	141486†	12	21	31	17	1u	1	0.1u
05/03/84	141939	1u	1u	1u	1u	1u	1u	0.1u
"	141938†	1u	1u	1u	1u	1u	1u	0.1u
06/29/84	340051	4.0	1u	1.0	1u	1u	1u	0.1u

u = Not detected at detection limit shown.
-- = Not analyzed.
† = Dissolved metals.

Appendix IV: Summary of runoff coefficient (C) values applicable to the Tacoma tideflats log sort yards.

Railroad yard	0.2 - 0.4	Lindeburg, M.R., 1981. "Civil Engineering Review Manual" (3rd ed.). Professional Engineering Registration Program.
Rural Areas: Cultivated loams and similar soils without impeding horizons.	0.40	Dunne, T. and L.B. Leopold. "Water in Environmental Planning." W.H. Freeman and Co., San Francisco, CA.
Permanent pasture, range-land and idle land with no appreciable canopy and zero percent groundcover.	0.45	USEPA, 1982. "Water Qulaity Assessment, A Screening Procedure." A Screening Procedure for Toxic and Conventional Pollutants: Part 1. EPA-600/6-82-004a.